National
Forest
System

Forest
Service
Research

April 1993

Eastside Forest Ecosystem Health Assessment

Volume V

A Broad, Strategic Framework for Sustainable-Ecosystem Management

This report is not intended to provide precise details on all aspects of ecosystem management. The report responds to seven questions concerning the sustainability of ecosystems in eastern Oregon and Washington, and the effects of historical management practices on sustainability of those ecosystems. This report is not a "decision document" as defined by the National Environmental Policy Act (NEPA). It does not allocate resources on public lands nor does it make recommendations to that effect. Implementation of ecosystem management on Forest Service administered lands in the responsibility of the National Forest System and Forest Service Research. Implementation is done through forest and project plans that are subject to the NEPA process of disclosing the effects of proposed actions and affording the opportunity for public comment. The information contained in this report is general in nature, rather than site specific. In making land management decisions and establishing standards and guidelines National Forest System personnel may consider this information as well as a wide variety of other information received in the course of complying with the National Environmental Policy Act and other laws. The opinions expressed by the authors of the papers in this volume do not necessarily represent the policy or position of the Department or the Forest Service.

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A BROAD, STRATEGIC FRAMEWORK FOR SUSTAINABLE-ECOSYSTEM MANAGEMENT

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Acknowledgments:

We thank the following technical reviewers for their comments on an earlier draft: Fatma Arf; Lincoln Bormann; John Beuter; Hanna Courtner; Patrick Cunningham; Lorraine Heisler; Robert Lee; Bruce Lippke; Chris Maser; Thomas Nygren; Douglas Ryan; Margaret Shannon; Phillip Sollins; William Sommers; Robert Tarrant; and Julia Wondelleck. We also appreciate the helpful comments of our anonymous peer reviewer, and thank the many people who helped prepare the report and who helped with various other administrative tasks: Ilean Butler; Gonzalo Castillo; Dee Gordon; Mark Nay; and Linda Yung.

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Preface

For decades, public forest lands of the United States have been managed with emphasis on providing wood for an expanding population with expanding appetites for wood products. The Multiple-Use Sustained-Yield Act (1960) proposed that National Forests be managed for "multiple uses and sustained yield of the several products and services...," but growing and harvesting commodities has remained paramount.

Using the best information available, managers of public forest land tried to sustain the flow of wood by using an array of silvicultural strategies, some of which didn't always work. In fact, some practices, such as excluding fire, resulted in undesirable conditions, including increased damage from insects and heightened threat of catastrophic forest fire. National Forests were recently directed to change to "ecosystem management" (Robertson 1992). Under this policy, the USDA Forest Service was directed to manage by applying a concept of ecosystem sustainability (Overbay 1992).

A letter (May 29, 1992) from Congressman Thomas S. Foley (Washington) and Senator Mark O. Hatfield (Oregon) to then-Secretary Edward Madigan drew attention to the forest health problems threatening long-term sustainability of forests in eastern Oregon and Washington. The letter noted that the Forest Service now recognizes that certain of its practices may have contributed to the problems and expressed concern over lack of relevant scientific information.

In response to the congressional request, the Forest Service created the Eastside Forest Health Panel of scientists and other professionals. The panel interpreted their charter as responding to a request to tell Congress and the Forest Service what must be done to manage public lands responsibly. A team of five biologists (which was expanded to the large Eastside Forest Health Panel who contributed to these volumes) was assigned to undertake three tasks:

- To assess the condition of forested ecosystems on the eastside of Oregon and Washington, and to evaluate the effects of past and current management practices (the assessment volume);
- To develop a scientifically credible framework for ecosystem management (the broad, strategic framework volume--this one); and
- To examine ways to apply landscape ecology to ecosystem management in National Forests (the application volume).

This volume is one of five (including one that summarizes the other four) prepared by the Eastside Forest Health Panel for presentation to the Chief of the USDA Forest Service in May 1993.

This volume consists of three parts:

- Section I is a 3-page paper with our most important conclusions and recommendations to Congress and public land management agencies, including the USDA Forest Service;
- Section II is a 16-page paper that outlines the framework on which the conclusions are based; and
- Section III contains the background and theory used to derive the framework and conclusions.

Contents

SECTION I: RECOMMENDATIONS

What should policy-makers do to achieve ecosystem sustainability?

The answer is to take bold action in policy, institutions, management, and research to implement sustainable-ecosystem management on public lands.

Sustainable-ecosystem management requires a legal framework that:

1. Defines ecosystem sustainability.

2. Decides the extent to which ecosystem sustainability and maintaining future options will be the primary objectives of ecosystem management.

3. Clarifies the context of public land management, including:

    - Coordinating with or superseding existing laws[1] and establishing policies to reduce litigative and interagency gridlock;

    - Coordinating with policy on global issues (warming, air pollution, balance of trade, energy policy, population growth);

    - Linking ecosystem management with rural development policy;

    - Funding public agencies to sustain ecosystems by means other than revenues from commodities;

    - Combining, with some caution, public agencies to better reflect an ecosystem approach; and

    - Excluding, temporarily, pilot National Forests from existing management laws, to develop the "manage as an experiment" concept for broad application.

4. Improves the decision process by:

    - Opening policy and planning decisions to full participation and shared responsibility by the public and scientists;

    - Defining different objectives at national, regional, and local scales and linking information upward and downward among scales;

    - Using different processes at different geographic scales to make decisions (national and regional decisions may be made most efficiently by elected officials);

    - Making decisions about combinations of practices, not practices independent of one another; applying scientific, managerial, and societal knowledge to define desirable combinations of practices;

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[1]Multiple-Use Sustained-Yield Act, National Forest Management Act, National Environmental Policy Act, Endangered Species Act, Knudsen-Vandenburg Act, Clean Air Act, Clean Water Act.

- Evaluating the effects of combinations of practices on maintaining options for future unexpected wants and needs;

- Creating opportunities for cooperative management with adjacent landowners; and

- Building a role for independent analysis, monitoring, and feedback.

5. Expands research on sustainable-ecosystem management to:

    - Become integral to "manage as an experiment" (scientists should participate in planning and monitoring; develop and test innovative practices and practice combinations; and help direct management through current and improved understanding of what is and is not biologically and physically possible);

    - Enhance the role of research as independent evaluator through retrospective studies of ecosystem sustainability, development and testing of measures of ecological capacity, and continually reevaluating the premises on which sustainable-ecosystem management are based.

The Forest Service should:

1. Continue to develop the theory and application of sustainable-ecosystem management; much remains to be resolved.

2. Apply the sustainable-ecosystem management ("lacing") model in a regional analysis of eastern Oregon and Washington.

3. Implement this framework for sustainable-ecosystem management, based on a 2-yr pilot study on one or more entire National Forests; eastern Oregon and Washington are good places to start because of apparent societal consensus on the problems. Implementing this idea will require policy and institutional changes to:

    - Convert management into an experiment (requiring a different decision process, personnel changes; and direct funding);

    - Elevate information to the status of primary resource; and

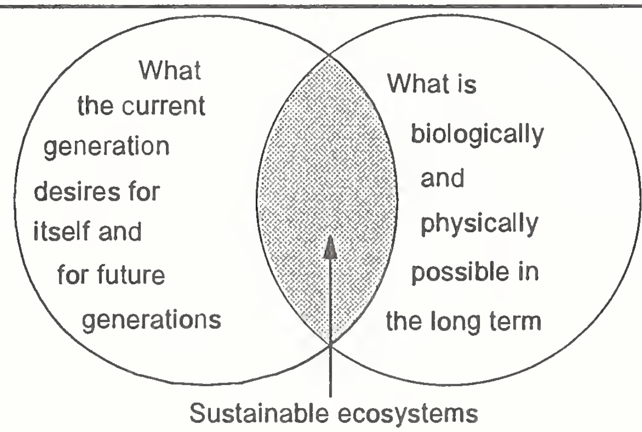
    - Avoid costly-to-replace losses of local intellectual and cultural information, skilled workers, and markets.

Although these recommendations may not apppear to substantially depart from current visions of ecosystem management, we believe that our approach is fundamentally different--so much so that implementing these recommendations may not be possible under current laws and policies. These recommendations are based on a framework for sustainable-ecosystem management that broadens the concept of management to incorporate more societal processes and natural and social science.

Our framework was developed by:

- Defining terms and concepts;
- Deriving management principles consistent with a set of integrated fundamental, societal, and science premises;
- Defining objective measures of ecosystem sustainability so that people will know when it has been achieved; and
- Building a decision process and management system to accomplish ecosystem management.

A product of these steps is our definition of ecosystem sustainability as a basis for ecosystem management:



Ecosystem sustainability: the degree of overlap between what is ecologically possible **and** what is desired by the current generation. We advocate that the desires of future generations be protected by maintaining options for future ecosystem goods, services, and states.

Our major findings are:

- Eastside problems extend beyond management practices and biology and extend beyond the eastside; solutions require including societal values and science in the management system. Major organizational change and perhaps new national laws will be needed.
- Integration of science and societal processes into policy-making is hindered by disciplinary fragmentation; solutions require continual analysis of underlying assumptions of science and society and deriving integrated management principles.
- We must go beyond adaptive management to managing as an experiment by including more science and societal participation, testing a wider array of treatments, predicting outcomes, and comparing actual to predicted outcomes.
- Because change in ecosystem condition, societal values, and knowledge is continual, diversification--of organisms, ecosystem patterns and processes, rural and national economies, and management approaches--is essential to ecosystem management.

SECTION II: THE FRAMEWORK

INTRODUCTION

People are just beginning to grasp the scope of ecosystem management. When the five biologists given this assignment first met to consider it, they studied the documents chartering the effort to be sure they understood its scope and direction. They wondered whether answering the questions posed by the documents would produce the information that the Congressmen, the Secretary of Agriculture, and the Forest Service really want and need to know to improve the health and sustainability of Oregon and Washington forests east of the crest of the Cascade Range ("eastside"). And they discussed some questions clearly not asked but needing to be addressed, so that answers to other questions would be useful to policy-makers and land managers.

On the surface, the legislators were asking for purely biological information: What biological limits constrain our ability to extract all the products and benefits society wants from ecosystems while maintaining the "sustainability" of the ecosystem? The Eastside Forest Health Panel identified problems specific to eastside ecosystems (table II-1).

Table II-1. Issues affecting condition of forests on the eastside of Oregon and Washington (based on a list composed by the science panel)

PRACTICES	POSSIBLE BIOLOGICAL RESULTS
Grazing	Degraded riparian areas and streams
Timber harvest	Reduced old-growth-dependent species; fragmented stand structures
Fire exclusion	Increased fuel load; overstocking; insect and disease problems
Irrigation diversion, dams, overfishing	Reduced anadromous fish populations
Deer and elk enhancement	Reduced diversity of shrubs and herbs and associated animals
Insect spraying	Damage to nontarget species
Introduced species	Severe competition with native species

Biologists can describe, though imperfectly, what conditions appear necessary to sustain the productivity of a series of commodities. But they cannot describe a management system to sustain a vague concept of ecosystem integrity. If ecosystem integrity means that all key components of an ecological system are intact and functioning normally, then they would need to know what those key components are and what normal functioning means.

Scientists are sure about some important components of ecosystems, like soil, air, water, and sun; they know a lot about some others, like nutrient cycling and the importance of insects and fungi in releasing nutrients; scientists are increasingly aware of such things as the effect of fire suppression and toxic substances; and so on. A lot is known about many organisms that appear to be useful or even essential to the functioning of the system--but nothing at all is known about many others. Some indicators that ecosystems are changing (or becoming "degraded") are recognized, like loss of biodiversity, disappearance of humus, altered hydrology, increased erosion, and so on. But scientists may still be unaware of some subtle, but key process or small, but ubiquitous organism, the loss of which could prevent that ecosystem from being sustainable under well-intentioned but still crude management. Neither biological nor societal standards for ecosystem integrity are possible because what constitutes "wholeness" for ecosystems has not been determined. Ecosystems constantly change--with and without human

activities--and components are added and lost, inputs and outputs change, and scientists cannot fully predict the future condition of ecosystems. Sustainability of an ecosystem, therefore, can only be approximated.

Problems--and Their Solutions--Extend Beyond Management Practices and Biology To Include Societal Values

Misapplication of management is a problem that extends beyond the choice of management practices and their biological implications. Management practices and societal demands and concerns are closely interrelated (table II-2). For example, a reason for high rates of timber harvest, grazing, water diversion and other commodities has been the high demand for cheap wood, beef, wool, and agricultural products. Concern also comes from citizens convinced that management practices harm them--for example the smoke from prescribed fire--or that many practices harm the environment.

Table II-2. The importance of societal concerns.

SOCIETAL CONCERNS	POSSIBLE RESULTING PRACTICES
Demands for commodities	Increased commodity extraction
Local job losses	Increased commodity extraction
Rural economic development	Increased commodity extraction
Ecosystem degradation	Wilderness preservation
Insect outbreaks	Spray programs; salvage logging
Inconsistent view of future forest	Inaction because consensus is lacking
Conflict among groups, based on values	Inaction because consensus is lacking
Acid rain	Liming of watersheds
Air quality from slashburning	Fire exclusion

We tried to separate biological and societal components in listing eastside forest health issues, but the difficulty of doing so only emphasized our belief that they cannot be separated. A wide variety of human influences and unpredictable events compound each biological issue in eastside forests. "Health" and "sustainability" are human concepts, and people's definitions may be very different. Although some would argue that all human actions are detrimental and that only landscapes untouched by people are natural, no parts of the globe have truly escaped effects of human activities. Our concept of ecosystem management is based on the belief that human actions can contribute to--as well as prevent--ecosystem sustainability.

Placing all responsibility for forest health on the forest, its processes, and the inadequacy of forest science ignores the triggering causes of forest health decline: society's failure to understand the limits under which ecosystems produce goods, services, and states for society--and society's failure to understand itself. Analyzing the options available to society for directing its own behavior to promote ecosystem health and sustainability is as important as research in natural science and land management. Changes in economic behavior, societal institutions, and the understanding and use of ecosystem information, psychology, and philosophy are needed to realize sustainable-ecosystem management. How people, especially the people entrusted with land management, contributed to the decline in eastside forest health, through imperfect understanding of societal and ecosystem processes, unintended consequences, and changing social objectives must be analyzed. And how people and their institutions will have to change to attain ecosystem sustainability must be recognized.

Given clearly expressed and compatible goals, natural science can provide assessments of which management alternatives are likely to be ecologically possible. And whatever management methods appear ecologically possible can be viewed as experimental, with close attention paid to their effects and the methods modified as results are collected and interpreted.

Many people are concerned about and distrust the decision process itself. They may be concerned about being included in developing or selecting alternatives--or whether they have a voice at all. People in other parts of the country also want a voice in how western Federal lands are managed. For ecosystem management to be successful requires a process where conflicts can be resolved--even though as one conflict is resolved, another emerges as the focus of debate. This debate is essential to democracy; and it defines the framework in which ecosystems are managed.

Problems--and Their Solutions--Extend Beyond Eastern Washington and Oregon to the Region, Nation, and Globe

The discovery that some past practices now appear to be undesirable is not limited to eastern Washington and Oregon; this discovery is happening on public lands nationally. We have considered issues broader than local application of management, their biological and social causes, and their implications. We chose also to consider the role of science and the public in the decision process, the structure of Federal bureaucracies, budgeting strategies, and conflicting laws that may severely limit management options, among other factors.

The organizational structure of land management agencies has often not been conducive to change and sometimes prevents adaptation of management activities to local conditions. Public policy is formed in the political arena, sometimes with little participation of those who know what is physically and biologically--as well as socially--possible, and it is often skewed by the special interests of those with power and influence.

The role of the public in decisions affecting land management is increasing, and people are becoming insistent in their demands to be heard. As the population expands and diversifies, conflict accelerates over what should be done and where and how much. Neighbors disagree, communities are divided, voices become shrill, and lawyers prosper. Scientists increasingly find themselves in court and before congressional subcommittees, arguing questions of science in an arena so charged that logical dialogue is impossible. What groups form the constituency for eastside forests must be determined, perhaps including some groups that may not yet have found their voices.

Effective communication of scientific and management concepts to the public is essential to the building of informed communities of interest. Strategies for negotiation among these communities must be developed so their input to planning is truly and fairly heard, understood, and incorporated both into good alternatives and good choices among them. Natural and social scientists must contribute to formulating public policy, with full recognition of the influence of their personal values and biases. A major barrier to the contribution of scientists is poor communication within and among disciplines, especially between the social and natural sciences.

Uncertainty and unpredictability of both natural events and human needs and desires affect ecosystem sustainability. The risk of catastrophe underlines the need to maintain options in managing the forests. Maintaining options is important because people's behavior--and thus their needs and desires--changes over time. Having to consider human behavior at multiple geographic and temporal scales expands the kaleidoscopic variation of human interactions with ecosystems beyond the bounds of easy analysis. People believe they have choices for how they influence ecosystems. Society has not always made choices that ensure ecosystems produce even what was identified as desirable. And society has often failed to see the consequences of its own expectations from forests until the capacity of the forest to fulfill societal needs is severely compromised and the effects of cumulative human actions produce a crisis.

Society's approach to these crises is to react in a big way. A widespread assumption is that all big questions can be answered by "throwing science" at them and that "technology will solve all the problems," but workable and ethical solutions require that scientists and social scientists and citizens and policy-makers all work together to find the answers. Despite human capacity to perceive big problems and research, analyze, and apply information to natural resource policy in the United States, the response of policy and policy-makers has not always been timely. The delay is not the result of inadequate expenditures of effort; the problem is that the connections between science, society, and policy are so tenuous.

Only within the context of these broader issues can long-term solutions to the problems of eastern Washington and Oregon be found. Thus, part of the solution will come from Federal policies and Congress itself.

DEFINE TERMS

Much is being said about ecosystem management, sustainability, integrity, health, and many other concepts, without adequate definition of terms. We emphasize that **all** of these terms represent human concepts and are therefore subject to the biases of human values. Terms are defined in shadowed boxes.

> **Ecosystem**: a system of organisms and their physical environment interacting so that a flow of energy leads to a clearly defined trophic structure (foodchain) and material cycling between living and nonliving parts. Ecosystem boundaries are designated to address specific problems, and therefore an ecosystem can be as small as the surface of a leaf or as large as the entire planet and beyond. Through movement of energy and material across the boundary, ecosystems affect and are affected by other ecosystems. Because people directly or indirectly influence all of the earth's ecosystems, and because people obtain sustenance and make demands from ecosystems, our framework includes people as an important part of all ecosystems and societal processes as important ecosystem mechanisms.

The new focus on ecosystem management by agencies that manage public lands is perceived by many people as an attempt to make management more ecologically based. Concerns are often raised that current management focuses too much on the individual ecosystem parts, such as timber, water, range, fish, and wilderness, and not enough on how the parts fit together and function as a whole. Ecosystem management considers these parts as a system, and not just as an assemblage of parts. We endorse this view, but extend it in two important directions:

- Societal processes, usually considered as a constraint to management, need to become more integral to the management system.

- Science, mostly an outsider to the decision process, must also become integral to the management system.

> **Societal processes**: (for the purpose of this document) how people collectively regard, affect, and are affected by ecosystems.

Ecosystems approach: the "system" in ecosystem embodies three fundamental concepts: designating the physical boundary of the system and its parts; understanding the interactions of the parts as a functioning whole; and understanding the relation between the system and its context. We define "context" to mean both the external factors that influence the system and also internal information that must be synthesized to be understood at the scale of the defined system. For a continental ecosystem, global air pollution and population growth are examples of external context and local political processes and endangered species are examples of internal context.

Ecosystem management must also be based on the understanding that ecosystems are constantly changing even without human influence. Disturbance, succession, and natural selection are important mechanisms of change in natural ecosystems. Parallel mechanisms bring about changes in society. An ecosystem management system therefore must be able to incorporate change, in societal processes, our understanding of natural and social phenomena, and in the natural capacity of the ecosystem.

Ecosystem management: a system of making, implementing, and evaluating decisions based on the ecosystems approach, which recognizes that ecosystems and society are always changing.

These intuitions led us to a conceptual model of the principle objective of ecosystem management, ecosystem sustainability (fig. II-1).

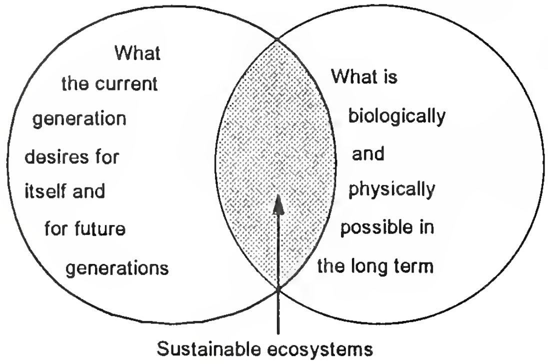


Figure II-1.
Ecosystem sustainability: the degree of overlap between what is ecologically possible and what is desired by the current generation. We advocate that the desires of future generations be protected by maintaining options for unexpected future ecosystem goods, services, and states (expanded in the definition of measures section, page 13).

Ecosystem health: qualitatively synonymous with ecosystem sustainability.

Ecosystem degradation: reductions in ecosystem sustainability because of natural or human effects.

Ecosystem restoration: increases in ecosystem sustainability after degradation resulting from natural processes or management.

DERIVE MANAGEMENT PRINCIPLES CONSISTENT WITH A SET OF INTEGRATED PREMISES

Ecosystem management requires a broader assemblage of elements of society and sciences than did previous management models. Including these elements requires that their underlying assumptions and biases be exposed and reconciled. This process must begin by recognizing that these assumptions and biases exist in both societal groups and science disciplines. Once reconciled, these assumptions and biases become premises on which ecosystem management principles can be built.

We derived a set of management principles (pages 9-13) from a synthesis of fundamental, societal, and scientific premises (pages 21-37). This synthesis--a vertical and horizontal integration of premises listed in table II-1--is possible because of recurring universal concepts.

Manage

Our framework is based on a fundamental premise, not held by all members of society, that human influence on the land can be made positive. When land is left alone, people often assume it to be solely under the influence of natural processes and capable of maintaining itself in some static state over long periods, but change is continuous. With the advent of global changes caused by carbon dioxide accumulation in the atmosphere, ozone depletion, and the spread of introduced species, no ecosystem is without the effect of human beings.

Human influences are clearly evident in the western United States, where, by not managing fuel loads and species composition, managers have in effect made large tracts of public land subject to increased insect outbreaks and disease, and have increased the potential for catastrophic wildfires, such as the Yellowstone fire in 1988 and the Spokane fire in 1992. Fire exclusion is a management policy that has avoided the more difficult task of managing fuel loads; avoiding problems by inaction does not solve them.

Use an Ecosystems Approach

The ecosystems approach (defined on page 8) is useful for understanding the complexity of societal values, ecological processes, and their interactions when combined in a management system. The current management system treats most societal processes and natural and social sciences as external context. Viewed as external constraints, societal processes and the sciences directly related to management compete for attention with an expanding set of issues such as population growth, global warming, energy policy, global markets, and endangered species legislation, to mention a few. If these related societal processes and sciences are viewed as part of the system, then they and the interactions among them will get the attention they need. An ecosystems approach recognizes that gains in one part of the system are often offset by losses in other parts of the system. It is in the interactions--among societal processes, both natural and social sciences, and management--that land management problems will be resolved.

Table II-3. Translation of fundamental principles, and societal and science premises, into principles for sustainable-ecosystem management.

Fundamental premises	Societal premises	Science premises	Management principles
Society and science are both influenced by individual and societal values, sometimes recognized but often forgotten.	People choose goals for future ecosystem goods, services, and states based on their perceptions of need.	Natural sciences recognize people as part of the ecosystem; social sciences recognize biological and physical constraints.	Manage. No management is poor management., although minimal management activity may be desirable i
	People group themselves into communities of common interests to advance their personal goals.	Science has roles both as forecaster and as conscience.	Use an ecosystems approach; integration of the parts of a system and its relation to its context are keys to improved efficiency and to understanding the system as a whole.
	Diversity, complexity, and the changing nature of human communities create uncertainty about demands and priorities both now and in the future.	Limitations of science must be understood; predictions should focus on ranges, rather than specific outcomes.	Consider information a primary resource; success of a management system depends on a decision process that includes adequate societal and scientific knowledge.
Good can come from management.	In a society of diverse and sometimes discordant communities, too many goals or conflict over goals may develop; some people may not get what they want.	Ecosystems are artificial constructs and therefore must be selected and classified with caution.	Develop communities of interest. A process is needed to draw all interested communities together into a larger planning community to develop and implement management policy.
Ecosystems are fundamentally complex and inherently difficult to predict	Ecosystem management decisions benefit from societal goals that are clear, informed, and integrated, and that recognize that ecosystems are complex.	Diversity is essential to adaptability--of organisms, rural and national economies, and public employees.	Apply general information carefully; considerable specific information and involvement of local human populations are needed to effectively implement management.
The entire system must be understood in its context; study of systems must include external factors and embedded processes.	Scientific and societal information are integrated and codified in laws, treaties, bureaucracies, planning processes, and budgets.	Ecosystem patterns and processes appear, and must be studied, at different geographic and time scales.	Manage across boundaries; to the extent that adjacent landowners have a common vision for ecosystem management, achieving multiple objectives will be easier .
	Policy will always be decided under conditions of uncertainty and ignorance.	Local conditions may override or obscure general patterns and processes; the general may not contain the particular.	Manage for change; diversification is the primary method for reducing risks of unexpected changes in future ecological conditions and societal demands (maintain options for future products).
	Unexpected ecosystem events and shifts in societal demands may require changes in societal institutions, and these changes will bring changes to society.	Ecosystem science at large scales relies on ecosystem management for empirical evidence; small, short-term studies do not extrapolate well.	Manage as an experiment; knowledge is needed from each management action by using a scientific approach that describes anticipated outcomes of an array of treatments and compares them to actual outcomes.

Consider Information as a Primary Resource

The National Environmental Protection Act (NEPA) process used by Federal land management agencies has produced decisions that are often legally challenged, as evidenced by the frequent court injunctions on management practices. Clearcutting and herbicide controversies were early examples; spotted owls and endangered salmon populations are more recent examples. Decisions that are more defensible will help to take management of Federal lands out of the courts. Defensible decisions require adequate information, openly distributed information, and better ways of including information in the decision process.

Elevation of information to the status of primary resource is essential to change the focus of agencies from resource outputs (timber, recreation, water, wildlife) to the generation, accumulation, and synthesis of information fundamental to sustainable-ecosystem management. Information on what the current generation wants, forecasts of what future generations are likely to want, and the ecosystem patterns and processes that can sustainably produce them are needed and currently lacking. Public participation in the decision process must increase. A more effective information system must be carefully designed to ensure a free flow of information between various geographic scales. Highly trained information professionals are needed in public agencies to translate complex scientific and management concepts for the broad audiences who are the agencies' constituents. Public land management must enter the information age.

Develop Communities of Interest

The public land management system should include mechanisms to develop broad communities of interest. We use the term "communities" to refer to groups of people with similar values and interests, not geographic assemblages. No matter how divisive demands of various communities may be, agreement on certain core values and commitments is crucial to community development that can aid in making decisions. Agreed-upon core values provide the common ground for discussion of management issues. Suggestions for obtaining these values and commitments for ecosystem planning are:

- A commitment to keep lines of civil and respectful discourse open and receptive to the views of others and to the possibility of change;

- A commitment to fairness and an equitable balance between the interests of individual communities and society for just distribution of rights and benefits from public lands; and

- A commitment to sustaining both ecosystems and societal welfare.

Apply General Information Carefully

Every ecosystem is a place, regardless of the designated boundary, and has unique characteristics; information from these places is therefore paramount. Perhaps the best established concept in forest science is that of site specificity--applied, for example, in the planting of tree genotypes. The principle of "apply general information carefully" applies much more broadly to include nearly all aspects of the ecosystem. A balance must be found between local and general information. Managing unique ecosystems particularly implies including human populations with local knowledge, some who are local in the sense of direct interest rather than geography.

Manage Across Boundaries

Ecosystem management requires different approaches to planning and coordination because ecosystem problems often cross ownership boundaries (SAF 1992). Managers also need to account for transactions across defined boundaries for different kinds of analyses. Common goals among neighbors permit coherent management for influences that extend beyond jurisdictional boundaries (migratory animals, air and water quality, fire management, insect outbreaks, and disease epidemics). Cooperative management requires joint goal-setting, compromise, regulation, and incentives. Clear communication is essential so that all parties are assured of fair compensation and equity. For example, the Blue Mountain Natural Resources Institute, a consortium of Federal, State, industrial, private, and tribal interests, was established to explore cooperative management on eastern Oregon forest lands. Federal lands must be managed in consultation with Native Americans because of treaty rights to resources on ceded lands.

Manage for Change

Change is pervasive in both societal values and the ecological capacity of the ecosystem. History clearly shows the importance of changes in social values and technology. The global ecosystem now appears to be changing much more rapidly than scientists thought possible (CO_2 and ozone). Changes can be predictable, poorly predictable, or entirely unpredictable. Thus, managers must recognize that they cannot manage for a specific desired future condition; they can only realistically manage for a range of future conditions. We draw an analogy to managing a securities portfolio of stocks and bonds, where the goal is to create a assortment of securities to achieve a sustainable mix of risks and rewards. Thus, sustainable-ecosystem management seeks to achieve such a ratio. The main risks are that societal demands will not be met and that long-term sustainability will be compromised.

Diversification is the primary tool for portfolio management to reduce risk; it is the classic form of hedging. Diversification can be achieved by managing for joint production from a place or from separate places designated for individual products. The concept of diversity and diversification is central to our framework, and it extends across all systems and their components. Benefits of increased diversity are assumed to be increased adaptability to our changing world--of organisms, rural and national economies, and public employees.

Manage as an Experiment

Managers have often assumed they understood the full implications of management practices. They assumed implicitly that few surprises--such as endangered species listings, regeneration failures, declining yields after repeated harvests, increased insect outbreaks, and increased potential for catastrophic fires--would follow. Events in eastern Oregon and Washington, and elsewhere, help to teach society that full ramifications of any management strategy will never be known in advance, if indeed ever. Thus, people who manage public lands have no other choice than to learn--from each management decision--to identify problems and implement solutions quickly. The fastest way to learn is to manage as an experiment.

Care must be taken to assure that this principle is not used as a license to implement a societally unacceptable agenda under the guise of "research." Thus, this approach cannot be applied by management agencies without changing to a process that shares decisions among the public, managers, and scientists. Experiments in clinical medicine may provide a partial model because both require human participants and ethical standards and regulatory guidelines.

Science has always had difficulty grappling with multiple resource management because disciplinary fragmentation hinders integration. Increasing the number of objectives greatly increases the number of practices and interactions among practices. In the past, science has strained to produce information on a set of practices much smaller and more widely applied than that proposed for ecosystem management. Information developed by traditional research rarely applies well to all of the great diversity of soils, vegetation, climates, past practices, and natural disturbance regimes; new approaches are needed (NRC 1990). If even small amounts of information at usable temporal and spatial scales are generated as a part of management, a great deal will be learned about how to improve management over time.

Managing as an experiment incorporates two science concepts as part of management: rather than implementing a single "best" practice, managers would implement an array of practices; and a scientific approach would be used to describe anticipated outcomes of the array of treatments and compare them to actual outcomes. These comparisons will be the foundation for efficiently building a theory of ecosystems on which ecosystem management can be more soundly based.

Managing as an experiment also includes society in the process of designing the alternate treatments to be tested in the management experiment. This process would identify a range of treatments, each of which consists of a combination of practices to produce what is desired by individual communities of interest. Treatments would be distributed across the landscape, perhaps with the cooperation of adjacent landowners. This strategy allows different communities to participate in the experiment.

Managing as an experiment is an important extension of the concept of adaptive management; it increases societal participation and the role of science, and it diversifies management practices, so that at least some of the alternatives produce desired results, rather than putting all of the ecosystem eggs in one basket. Scientists, independent from management institutions, would help evaluate the effects of the different treatments from a scientific perspective. Experiments would be simultaneously evaluated by managers and members of society as well. Together, these groups would gain the information needed to design the next experiment.

Ecosystem management is demanding: it will demand a competent, skilled work force made up of people who are always learning. Competence will require both depth of specialization and integrative breadth of knowledge. Uniformity of employee opinion and outlook has often been prized in public agencies, but such limitation of view may provide blind-spots as well as unity of purpose. Developing and nurturing a range of outlooks may redefine the core purpose for serving society.

DEFINE OBJECTIVE MEASURES OF ECOSYSTEM SUSTAINABILITY SO THAT PEOPLE WILL KNOW WHEN IT HAS BEEN ACHIEVED

Measuring the success of sustained-ecosystem management is required for its application. If we could define what is desired by society **and** what is biologically possible (fig. II-1), then we could determine whether any overlap exists, whether current management is in the overlap area, and the extent of the overlap. This approach is limited without common units to express ecological and societal conditions.

Fundamental integration of societal values and ecological capacity of the ecosystem led us to develop a new approach for measuring what people want and what is biologically and physically possible. We attempt to tie together societal values and the social and natural sciences into a common framework on which to base sustainable-ecosystem management. Ultimately, the

success of this integration will be determined by developing measures to evaluate whether objectives have been achieved. These measures should be based on understanding:

- The broad range of societal values ("products") desired now and in the future from publicly owned ecosystems,
- Ecosystem patterns and processes required to produce each product, and
- The interactions between ecosystem patterns and processes required to produce each product.

> **Products:** all possible goods, services, and states that society desires from the ecosystem, including commodities; services, such as recreational opportunities and clean air; and states, such as attractive landscapes, and abstract entities, such as biodiversity. Production is the flow of products, as defined above. States result from ecosystem development processes and from management actions.

No existing units simultaneously describe societal acceptance and ecosystem patterns and processes. We have begun to develop these units by suggesting that societal values can be expressed in common units of ecosystem patterns and processes thought to be required for their sustained production. This complicated concept is elaborated in section III. Patterns and processes that are identified as being crucial to the production of desired products can be compared with patterns and processes actually achieved after management has been attempted. This ratio of predicted to achieved, when multiplied with like ratios from all other socially desired products, makes a unit we call the Pinchot Standard, after Gifford Pinchot, the first Chief of the Forest Service. This approach requires that we begin to understand the patterns and processes required to sustainably produce **each product** that society identifies as desirable. Management as an experiment is required to improve this understanding.

A measure of ecosystem production per unit land area is also needed to compare ecosystems of varying inherent productivity. We derived a measure, called the Pinchot Efficiency, that increases when more variety and greater amounts are sustainably produced from a fixed land area.

The common-units approach relies heavily on an understanding and weighting of what people want, and thereby argues for increased public participation in decisions. Moving from public involvement to public participation is necessary to implement ecosystem management. Beyond identifying this as a key research need, this subject is beyond the scope of our framework.

Because societal desires, like biological processes, change over time, what is desired today may not be desired by the next generation; what is unvalued today may become very valuable in the future. For example, yew trees were not highly valued until scientists discovered that yew contained the valuable anti-cancer drug taxol. Society could choose to define sustainability as a list of products that do not include options for future generations. Although not considering future generations would satisfy our limited definition of sustainability, we believe it would be a tremendous mistake.

Because we cannot accurately predict what people will want in future generations, unexpected options must be represented by general ecological patterns and processes in ecosystems. Existing laws allude to aspects of maintaining future options. The Multiple-Use Sustained Yield Act (1960) seeks to protect the "productivity of the land." The Endangered Species Act (1973) seeks to reduce extinction of threatened species. Also, the "Gang-of-Four" report (Johnson et

al. 1993) developed "health" criteria, including protection of the spotted owl and other old-growth-dependent species and endangered salmon populations.

We propose to begin with an expanded set of broad ecosystem measures of ecological capacity that--if maintained--will likely lead to protection of desired future options. The set of ecosystem measures to be maintained is:

- Biological adaptability, measured indirectly through changes in diversity (in species or ecosystem patterns and processes);

- Energy capture by green plants, measured directly or indirectly through changes in soil properties;

- Water quantity and quality; and

- Air quality.

If these four measures--adaptability, energy capture, water, and air--are maintained, then many future options are also likely to be maintained. These measures, if maintained, also hedge against inadequate knowledge of patterns and processes needed to sustainably produce what people want now.

The measures we propose, however, are not enough. For example, an attractive ecosystem is likely to be highly valued but is not well represented in the measures proposed. Economic growth in the Pacific Northwest during the recent recession suggests that quality of life can be considered a second pay check (Whitelaw and Niemi 1989). Certainly, production of plants and animals is the foundation for aesthetics, but rock outcrops and other "degraded" lands might also be considered attractive, especially to generations that have become accustomed to them. For example, Mediterranean soils have been highly eroded through overcutting and overgrazing (Thirgood 1987), but the current vegetation is widely regarded as attractive. Thus, further work is needed to represent these subjective values in ecological capacity measures used to monitor future options. Some societal measures, such as energy consumption and the quality of education, may also indicate changes in future options. For these reasons, we do not propose this list as definitive, nor do we believe that scientists alone can make the choices. A clear connection must be sought between these measures and what people are likely to want in the future, and thus people need to help select these criteria.

Maintaining future options may not be related well to perceived forest health issues. For example, insects and diseases may actually increase biodiversity by increasing food supplies for predators and decomposers. Total energy capture by green plants may not decline if shrubs and herbs are included in the measurement, and trees tend to grow faster several years after a partial defoliation, perhaps because of enhanced nutrient cycling. In only the severest cases, defoliation might increase erosion and stream sediments, reducing some measures for maintaining future options.

BUILD A NEW MANAGEMENT SYSTEM AND DECISION PROCESS FOR ECOSYSTEM MANAGEMENT (THE "LACING MODEL")

Ecosystem sustainability, as we have defined it, is merely an interesting notion unless we have a management system that can implement it. Many eastside ecosystem problems are due to an inadequate and slowly responding public land management system. We propose a new management model that includes more science and societial processes. This model expands steps to analyze context and define objectives, and allows free flow of information. These

changes in approach to management are sufficiently great that they would require substantial institutional changes in both management and research agencies and perhaps changes in the legal framework.

> **Lacing Model:** an ecosystem management model that focuses on carefully defining objectives by iteratively "lacing" together societal values with knowledge of the ecological capacity of the ecosystem, and passing information openly between different geographic scales.

An Ecosystem Management System (the Lacing Model)

Our management principles suggest that the effectiveness of the management system depends on the number of internally defined processes and their interactions as well as the remaining processes excluded from the system (fig. II-3). If too many processes are included in the system, then their interactions make understanding and manipulation difficult. If the definition limits the system to a few internal processes, then the external context begins to dominate. A balance between these extremes helps to define a system in a way that is responsive to both internal and external influences. Including more societal processes and scientific knowledge in the system will achieve a better balance, which will improve decisions and increase societal acceptance.

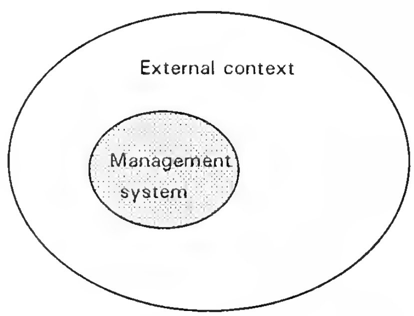


Figure II-3. A management system consists of interacting internal processes and constraints imposed by the external context.

For Federal lands, the management system must transcend a wide array of geographic scales, from local to national. Division of effort into multiple scales is required, for example, to allow decisions on National Forests in the West to include urban easterners and at the same time be based on local knowledge and participation by local community members. We propose a model with three interacting scales that do not correspond with the current organization of Federal land management agencies (fig. II-4). This model does not imply a top-down or bottom-up decision process; it focuses on information flow between scales in both directions. Although we believe a mixed top-down, bottom-up decision process is best, we recognize that balancing the needs of local areas against the common needs of a region or nation is a sensitive political issue.

The selection of geographic scale of the regional and local subsystems is an important issue. From a biological perspective, the regional scale should be as large or larger than the home ranges of most far-ranging animals and discrete assemblages of plant species. This size is highly variable because species can be distributed in very small areas or across the globe. Basins of large rivers like the Columbia could form regions. Even this scheme does not work well for fish like Pacific salmon that spend most of their lives in the international waters of the Pacific Ocean. Neotropical birds depend on winter ranges in Mexico and Central America. Cooperative management across international borders is appropriate at the national scale.

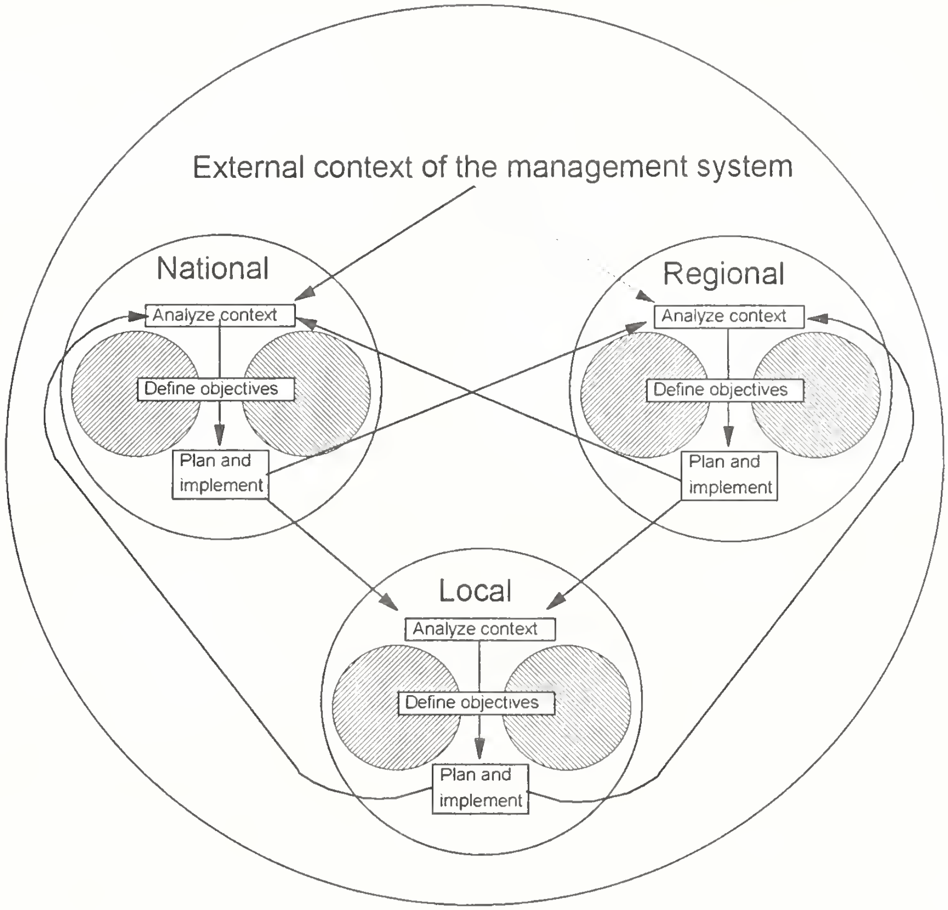


Figure II-4. Information flow in the multiscale management model. Note how the context includes information from both larger and smaller geographic scales. The two shaded circles in each scale represent societal values and ecological capacity. Scales listed do not necessarily relate to existing Federal agency structure.

From a societal perspective, regional decision-making might be enhanced by State political processes. Representative government could express people's demands. If the U.S. Congress wants to oversee regional decision-making, however, then a focus on States might be less important. This relation is demonstrated as a dashed line on fig. II-4. From a technical or logistic perspective, proximity is important, but perhaps decreasingly so, because of advances in telecommunications and transportation systems. A compromise position would be to join adjacent States with similar physiographic and socioeconomic conditions. This question needs further attention, however.

A Decision Process for Ecosystem Management

The decision process begins with an extensive analysis of context that combines information external to the management system and information synthesized from other subsystems (fig. II-4). We propose an expanded process of defining objectives that focuses on our ecosystem goal of achieving what is biologically possible **and** what society wants for itself **and** for future generations (fig. II-5). This process can be viewed as a iterative interaction of analyses that have the goal of maximizing the overlap that we describe as ecosystem sustainability. Sustainability will be achieved only through the right combination of practices; individual practices, by themselves are of little significance.

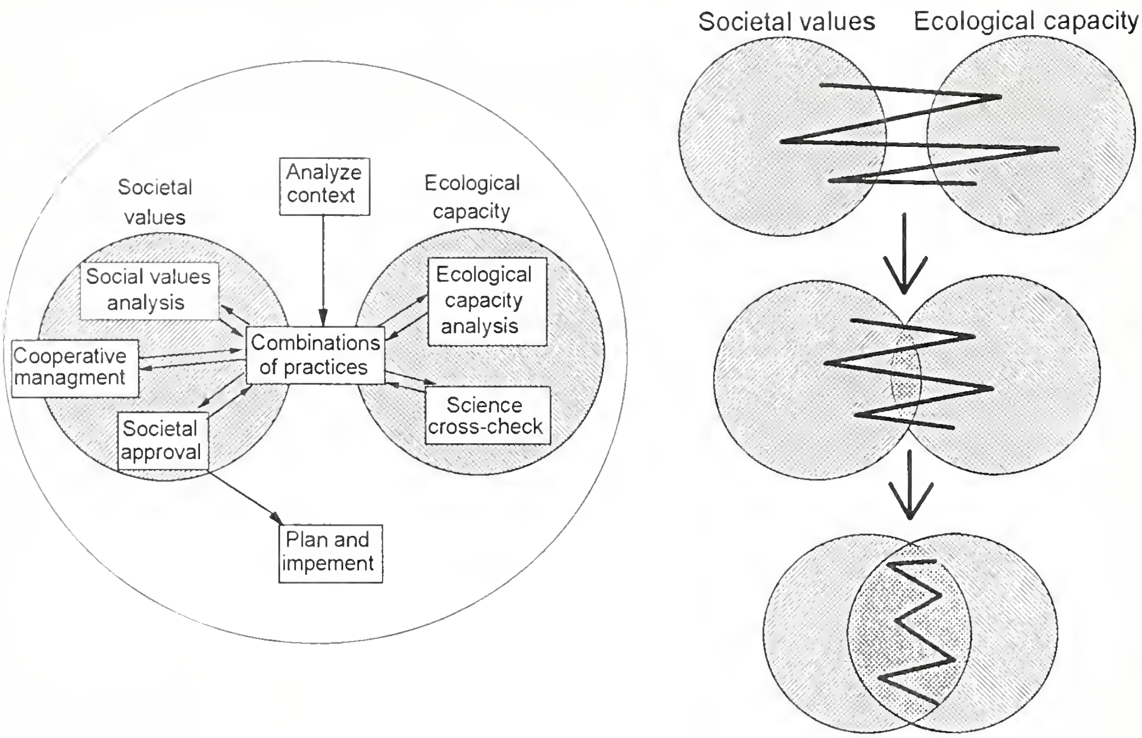


Figure II-5. An iterative decision process for any geographic scale to "lace" together societal values and ecological capacity of the ecosystem. Success in this process will produce overlap as shown in fig. II-1.

Analyses to Define Objectives at Each Scale

Context analysis. The context establishes constraints and remaining options for management. These constraints are more fluid than traditionally conceived constraints, in that negotiation between scales to increase management options is encouraged.

Societal values analysis. To be adequately informed with societal information, this process at all scales must include the public as a full partner in reaching decisions. For the national and regional scales, efficiency of public involvement might be increased by working with elected officials as representatives of the public to help in the decision process. This process should begin by using established social science methods. Ideally, in retrospect, public input should be included in exercises like the one we are currently doing. Decisions must be based on information about the societal costs and benefits of proposed combinations of practices. All costs should be considered, including those of operating a bureaucracy.

Ecological capacity analysis. To be well informed, the decision process must also include the best available scientific knowledge. An analysis of combinations of practices is needed to remove from consideration those that are not biologically or physically possible. The objective of this analysis is to look at each practice as it influences the possibilities of achieving the extent, intensity, or duration of each other practice (for example, extensive salvage or grazing may not be compatible with extensive stream restoration). Defining these perceived incompatibilities also produces an applied research agenda (for example, what spatial or temporal solution would allow both high salvage or high grazing **and** high stream restoration?). The analysis would identify the patterns and processes necessary to sustain desired products

and also address how possible combinations of practices affect long-term measures for maintaining future options. This process would likely involve a mix of professional and scientific judgment and computer or other model simulations because data for many combinations are lacking. A significant role for research is to re-define and test measures for maintaining future options, which could also become the focus of a regional monitoring program, requiring improved remote sensing methods. Note that monitoring of societal acceptability will also be required. Monitoring becomes evaluation of the experiment when the approach used is "manage as an experiment."

Cooperative management opportunities. Combinations of practices on adjacent ownerships might allow equitable tradeoffs that increase both individual and collective values. When actions on adjacent non-Federal land act to build ecological capacity or satisfy societal demands of the larger ecosystem, then additional combinations of objectives should be considered (SAF 1993). This alliance of objectives is how we define cooperative management. Remote sensing might play an important role in acquiring information. A new reporting system might also be considered, at least for industrial landowners.

Independent cross-check analysis. An independent scientific evaluation of the management system is needed to evaluate whether management is in line with principles of sustained-ecosystem management. Preferred combinations of practices could be compared with an established list of premises and principles (pages 21-37), which would help to assess progress toward objectives independently. Research and synthesis activities are required to continually update this list. A scoring system could be developed to apply the cross-check as a simple model. The need for independence in science argues for institutional separation of management and research.

Societal approval. Increased consensus on management objectives for the National Forests is needed. Representative government has a role and responsibility in building this consensus at the national and possibly State (regional) scales. As their name implies, special interest groups often inhibit consensus on management objectives as a whole and instead promote their individual objectives. This tendency must be overcome to make significant progress.

In addition to establishing consensus on difficult issues, representative government could simultaneously deal with the issue of how to pay for ecosystem management. If the Forest Service is to stop--as we have recommended--the practice of paying for most activities through a timber-driven budgeting process, then direct appropriations will be needed to fund nonmarket activities. This way of budgeting would factor in the cost of various combinations as well as the benefits.

CONCLUSION

Consistent use of these principles would improve the management of public lands. But the knowledge they require makes ecosystem management more difficult and more expensive than managing for commodies. Much more information and participation from society and science are required to make better long-term decisions. Solving a variety of production and preservation problems requires a broad range of technical knowledge, social skills, and the people who collectively embody them. An important question for ecosystem management is, "Can society afford it?" The severity of current problems, however, begs the opposite question, "Can we afford **not** to apply it?"

Louis, by the Grace of God, King of France and of Navarre: To all in the present and future, Greeting. Although the disorder which had slipt into the Eaux et Foret of our kingdom had become so universal and so rooted that the remedy of it appeared to be almost impossible; nevertheless, Heaven has so favoured the application of eight years which we have given to the re-establishment of the noble and valuable portion of our domain, that we see it to-day in a more flourishing condition than ever before, and producing to the public all of the benefits which could have been expected from it, be it the conveniences of private life; be it for supplying the requirements of war; or be it, in fine, for the adornment of peace, and the increase of commerce by lengthened voyages in all parts of the world. But as it is not enough to have re-established order and discipline, if we do not by good and wise regulations see to it that the fruit of this shall be secured to posterity.

Ordinance of Louis XIV, King of France and Navarre, relative to water and forests, 1669.

Translated by John Croumbie Brown, 1883.

SECTION III: BACKGROUND AND THEORY

INTRODUCTION

The quotation from Louis XIV (previous page) shows that people have been trying to manage forests for posterity for a long time. How is our approach different? Louis XIV and the French foresters of the time held two key assumptions that are implicit in the quotation:

- We know what we want from the forest now and for posterity.

- We know how to manage the forest to secure what we want now and for posterity.

Taking these assumptions as true means that devising a system of forest management consists simply in specifying a set of rules and regulations about how the forest is to be used and treated--which is what the French Forest Ordinance of 1669 did. But the ordinance, like forest management decisions of today, has failed to recognize that societal needs and wants change and that ecosystems are complex and frequently unpredictable.

Our assumptions for ecosystem management are quite different:

- We do not now know all of the uses of a forest that will appear in the future. We assume that ecosystem management is driven by goals determined by society, and that these goals will change through time.

- We recognize that we have limited knowledge of the multitude of physical and biological processes that act to provide those aspects of the forest that we desire. We assume that forest ecosystems are complex and frequently unpredictable, and we are constantly updating our knowledge of their dynamics.

We have derived a management system that we believe is more realistic and more durable than that of Louis XIV. We first present our most fundamental premises (page 21-37). A vision of how society functions and how it affects and is affected by forest ecosystems begins on page 23. An analysis of the role of science and technology in ecosystem management, begins on page 32.

Management system fundamentals (discussed on page 38) combine with management principles (page 9) to develop a sustainable-ecosystem (lacing) model (page 15).

A theory and definition of sustainability for forest ecosystems is developed on pages 42-51. Here we introduce and develop the idea of the **Pinchot,** a unit of measure for production of a sustained forest ecosystem managed for societal goals. This unit is important because we will know a sustainable forest ecosystem is achieved only if we can measure sustainability.

We briefly discuss the difficult problem of how to increase public participation in ecosystem management on page 51. A role for research in sustainable-ecosystem management is also described (pages 52-54). And, finally, we include a list of the major implications of our approach (page 54).

SOCIETAL AND SCIENCE PREMISES

Fundamental Premises

As the Chief's decision to change to ecosystem management indicates, some serious problems have been identified with the way the Forest Service was doing business, . The Forest Service faces a revolution at least as great as is being faced by Digital Equipment Corporation and International Business Machines. Like the Forest Service, these companies are large and have been highly successful in the past. And also, like the Forest Service, they have recently recognized the need to rethink the very basis for their existence or face extinction.

We consider four premises as fundamental because they apply to any management of any ecosystem. The premises grade into societal, social and natural sciences premises, and management principles, but they apply no matter what other principles we choose. Fundamental premises describe conditions that must be acknowledged to proceed with ecosystem management and may also give instructions on how to accomplish it.

Premise 1. Science and society are both influenced by individual and societal values, sometimes recognized but often forgotten. Implementing ecosystem management requires greater participation by society and more scientific information than does managing for a series of commodities and benefits. How citizens and scientists will participate is a critical component of any approach to ecosystem management, as is recognizing how the beliefs and biases of both groups influence their willingness to participate and their effectiveness. These underlying assumptions of the sciences and society must be exposed and reconciled as a basis for ecosystem management.

Societal assumptions. Society operates with sets of underlying assumptions--sometimes recognized but often hidden. The need for societal consensus as a basis for managing public lands requires that the assumptions be acknowledged, examined, and reconciled. We have proposed a set of fundamental premises (table II-3) that underlie our approach to ecosystem management, as a starting point for the search by ecosystem management stakeholders for the premises that guide them.

What groups and individuals want and need from ecosystems is highly diverse; the ability of public land managers to function requires that these groups and individuals negotiate--and ultimately agree--about what the goals should be. The first step toward resolving conflicts among all these different interests is open discussion leading to a common set of premises under which the individuals and groups agree to operate. Social science research has developed and tested a variety of conflict resolution and consensus-building strategies that can support goal-setting for ecosystem management.

Science assumptions. Science also operates with sets of underlying assumptions, although people--and often scientists themselves--are less able (or willing) to recognize this "human" quality in science than in society. We agreed to certain science premises (table II-3), not as a final list, but sufficient to begin the requisite dialogue.

Science has many disciplines, each with a set of underlying assumptions passed to new generations of students and rarely questioned. Science can be correct within paradigmatic constraints, but underlying assumptions often differ between disciplines. Ecosystem management requires information from a multitude of disciplines; to be useful, that information must be integrated. Differences in underlying assumptions are often serious barriers to integration.

Science is divided into natural (ecological) and social science. Natural science is split into botany, zoology, geology, physics, chemistry--and those into subdisciplines such as plant pathology and

plant physiology, entomology and herpetology, geomorphology and hydrology--and so on. Social science is split into economics, sociology, history, psychology--and those into subdisciplines such as microeconomics and macroeconomics--and so on. And each discipline is split into schools of thought and various contending camps with differing perspectives, each equally valid under its own paradigm. The size, complexity, and--especially--the fragmentation of science work against the kind of research needed for ecosystem management, which focuses on wholeness, integration, and simultaneous consideration of the objects of all these various disciplines (NRC 1990).

Integrated research has often been tried, but commonly fails because the disciplines do not share a common vocabulary, work at widely differing scales of time and space, and fail to understand the underlying assumptions of other disciplines. Scientists must be encouraged to step across disciplinary boundaries to undertake the cross-disciplinary research that ecosystem management needs. They will need to challenge their own biases, expose and question their own discipline's assumptions, and demand that their colleagues in other disciplines do the same. Note that the current reward system in science operates strongly against this process. For example, universities need to be encouraged to allow students to combine solid foundations in two or more disciplines to build degree programs tailored to this kind of research future.

Science is widely perceived as value-free and entirely objective, but what scientists choose to study and the particular questions they address are partly based on the values of the scientist and science disciplines. The system of hiring and promotion for scientists rewards small pieces of original work by an individual more than it rewards synthesis, teamwork, or interdisciplinary efforts. Fostering integration--and insisting that the quality of such efforts be high--will produce the policy-relevant science essential to ecosystem management.

Scientists often are called upon to give advice on policy. Policy-makers expect such advice to be solidly based on experimental evidence, but, in the absence of requisite data, may call upon the scientist for an expert opinion. So long as all parties recognize that **opinion** is being solicited and given, science is not compromised. But science is compromised if the scientist conceals the biases and assumptions on which the opinion is based.

Major advances in science often result from interdisciplinary work based on a revisiting of underlying assumptions. By applying this approach, we seek a major advance in science that will allow us to contribute to developing more harmonious relations between human needs and the environment.

Premise 2. Good can come from management. Managers must be optimistic about what management can do: that is, they must believe that their management actions will indeed have beneficial effects. This assumption implies that managers have a clear idea of what they are doing and why. Not everyone concerned with ecosystem management assumes that the work of management is beneficial, and some people believe that **all** human actions in the forest are detrimental. Those who do not accept that human actions can be beneficial must recognize that managing ecosystems by a complete "hands-off" policy creates its own particular results and incurs costs to society. In responding to Henry Tryon's account of the work at the Harvard Black Rock Forest, Trow (1984) sees a fundamentally optimistic view of forest management:

> There is a trust in the possibilities of work. A man who had come to distrust the work of men might have said, "See here, this is good. Let us at least keep our hands off this." A devilish man who had come to despise the work of men might have said, "This is good. What of it?" Tryon's opinion is one never heard in our day: "This is good. Let us put our good hands on it."

But to even begin thinking about ecosystem management we must share Tryon's opinion.

Two forms of trust are important for public land managers: trust in themselves as competent practioners of their craft and the trust the public has in them. Public trust needs to be continually won, but to earn or regain it, managers must have confidence in themselves.

Premise 3. Ecosystems are fundamentally complex and difficult to predict. The science of evolution focuses on the variability of the natural world and how that variability is generated and maintained. Much of the variation, however, has a large, often dominating, random component. Most, if not all, of the processes in an ecosystem are highly variable over some scales of space and time. Thus, a view of the world as uncertain is needed for ecosystem management.

Even where the variation in nature is limited to a range, the amount of unpredictability can be high and managers are constantly surprised by unanticipated fluctuations (Heyde and Cohen 1985). If processes remain similar and the random component is drawn from a fixed distribution, then the unpredictability of the system can be characterized by statistics. If, as is often true in ecosystems, however, the processes change and the random component does not have a fixed distribution, then history does not accumulate in such a way as to give improved guidance to the future, and statistics are of little help (Lewontin 1966).

Premise 4. The entire system must be managed in its context. Once an ecosystem has been delimited for the purposes of management, the world outside the ecosystem must not be ignored. No ecosystems are immune to the effects of the outside world. For example, air pollution generated far away may directly affect a particular ecosystem such as a wilderness that does not itself produce any air pollution.

Having identified an ecosystem, management should proceed in such a way that, at a minimum, the system as identified survives through time. Beyond this minimum, management needs to trace the patterns of interconnection between the components of the ecosystem and the way in which management actions propagate effects through the system.

Society in Ecosystem Management

Emphasis in ecosystem management has concentrated on defining management practices, such as fire, grazing, and silvicultural treatments, to achieve future desired conditions. Applied research can support ecosystem management by developing and improving practices as means to achieve management ends more satisfactorily. The effects of ecosystem management on society have received little attention (Stankey and Clark 1992), even though society is the client for ecosystem products and future conditions. Research has paid even less attention to understanding the effects of present or evolving societal belief systems, political institutions, and economics on the theory and practice of ecosystem management.

No one fully understands ecosystem management. Here, we present a framework of premises about society that place society squarely within ecosystem management. Four major directions of inquiry are involved: sociological, political, cognitive, and economic. Along with premises about science (see page 32), these eight premises about society in ecosystem management define the relation between people and their ecosystems.

Premise 1: People choose goals for ecosystem goods, services, and states based on their perceptions of needs; goals are set and evolve by cultural and political processes. People have basic needs for survival and satisfaction. For example, Maslow (1970), includes as basic types of human needs, physiological survival, safety, love, esteem, self-realization, comprehension, and aesthetics. Ecosystems fulfill human needs by generating goods (timber, elk, salmon), services (air quality, recreation), or ecosystem states (biological diversity, old-growth forests). Everyone has his or her own list of needs and desires.

An ecosystem resource is valued as a resource only when people perceive it to be a resource. Recognition of a resource may become conscious only when the resource is becoming scarce. People may change their relation to an ecosystem resource as their culture and held values change because the types of value sought, the economic worth of the resource, and the community that uses the resource change over time (see fig. III-1).

As some needs are satisfied, demand grows for other needs, and wholly new and unexpected demands may emerge. As people strive to manage ecosystem processes for their advantage, ecosystems evolve whose function and look are shaped as much by ongoing human efforts to supply human needs as by inherent ecosystem processes (Hiss 1989). People in eastern Oregon and Washington, for example, perceive that local ecosystems are no longer meeting management goals and human needs. Both technical experts (Gast et al. 1991) and the general public (Starr and Quigley 1992, McLean 1992) are concerned with the decline in availability and quality of ecosystem goods, services, and states.

Goals for ecosystem management are not set by science, even though an attempt may be made to attain them through science. Goal setting is probably the most difficult part of ecosystem management. Allen Savory (1988) quotes Albert Einstein: "Perfection of means and confusion of goals seem, in my opinion, to characterize our age." and emphasizes that the ability to implement actions often overwhelms people's wisdom in deciding what to do.

Premise 2: People group themselves into communities of common or complementary values and interests to advance their personal goals. People with similar cultures, held values, or economic values (fig. III-1) band together out of need, be it for safety, esteem, or acquiring goods, and make common cause as a community within society. Aggregations of individuals into one or multiple communities, and smaller communities into one or more larger communities, give rise to complex kaleidoscopic scales of community organization. These community scales also exist in time and space alongside and within ecosystems and hierarchies of political and geographical organization (fig. III-2).

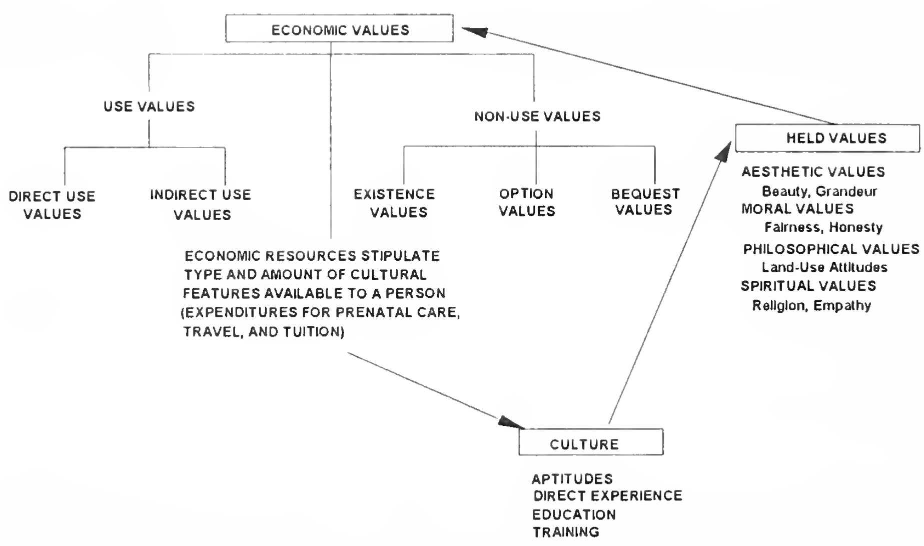


Figure III-1. Culture, held values, and economic values; arrows indicate direction of influence. Adapted from Brown (1984) and Turner (1991).

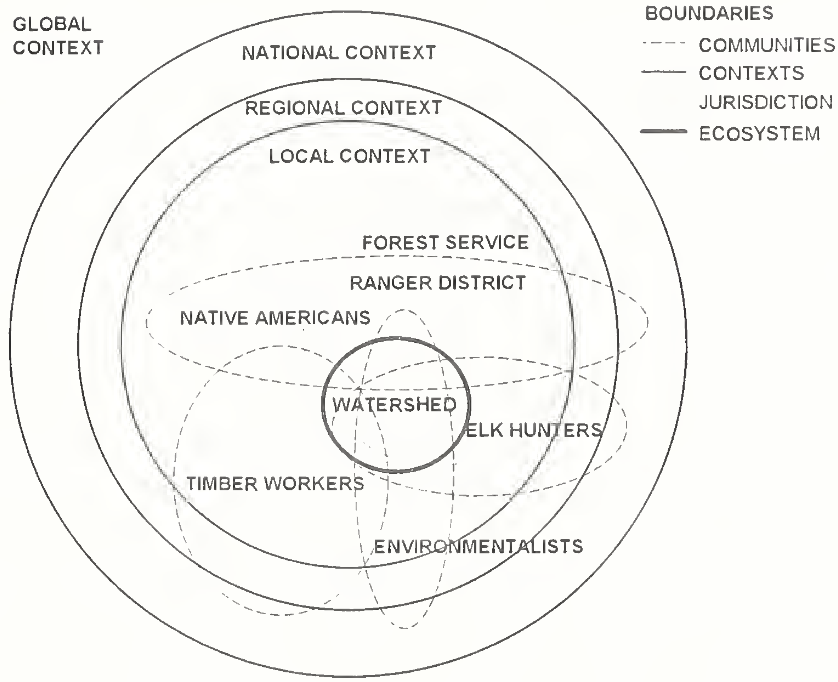


Figure III-2. Communities, context, and jurisdiction in ecosystem management policy. People's interests are represented by several communities; for example, a person might simultaneously be a timber worker, an environmentalist, and an elk hunter. An individual community has interests that span multiple geographic and political scales simultaneously. Multiple communities from multiple scales express interest in local ecosystem management on national public lands. Multiple jurisdictions over an ecosystem (here, a watershed) complicate ecosystem management further.

People in communities advocate general philosophies to explain their use of ecosystems to satisfy human demands. Examples are subsistence (hunter-gather or crop-based); resource mining; sustained yield of a single or major good or service; wilderness preservation for nonmarket goods, intangible services, and ecosystem states; multiple extraction of goods and services (multiple-use); or sustainable extraction of multiple goods, services, and ecosystem states. In addition, notions of ethics (stewardship, husbandry, or conservation of productive capacity of ecosystems) establish individual and communal notions of reciprocity and responsibility of people to ecosystems--an ecosystem contract, so to speak. People believe they are obliged in varying degrees to tend or manage the ecosystems. Taboos, rites, social customs, and political institutions manifest the existing ecosystem contract between society and ecosystems (Glacken 1967).

Communities create visions of the future and plans to achieve the desired future condition. They strike different balances between use, stewardship, regard of ecological constraints, and human self-restraint in their efforts to develop and advocate a path for ecosystem management.

Premise 3: The diversity, complexity, and changing nature of human communities create uncertainty about societal demands and priorities for ecosystem products, both now and for the future. Because human needs, objectives, and behavior in ecosystems are diverse, the range of ecosystem goods, services, and states demanded by people is highly variable. Managing National Forest ecosystems has focused historically on a narrow range of ecosystem products for a narrowly defined constituency. Recognizing the difference in cultural and class values placed on natural resources by different ethnic groups, urban and rural dwellers, rich and poor, is crucial to creating successful ecosystem management. How an expanded awareness of diversity of demand and priorities translates to managing specific ecosystems, now and in the future, is highly uncertain. Who participates in and who makes decisions are deservedly subject to debate. Diverse and

conflicting demands require balancing individual and collective preferences over the scales of political and ecosystem organization.

Individuals or communities may have different priorities for different ecosystems or may set conflicting priorities about values from a single ecosystem. For instance, Euro-Americans do not consider lampreys valuable, but Native Americans in the mid-Columbia River Basin prize them as a traditional food (Hunn 1990). Not unexpectedly, individuals or communities are inconsistent about perceived goals toward forest ecosystems. Many Americans feel profound attachment to wilderness experience. At the same time, many Americans have high expectations for consumption from ecosystems that are inconsistent with preserving wilderness. The set of goods, services, and ecosystem states to be derived from an ecosystem may be unclear in the minds of individuals, communities, or society as a whole.

Public land management currently flounders because of rapid societal changes that make definitive and effective responses by policy-makers and ecosystem managers difficult (Koch and Kennedy 1991). Changes create societal stress and conflict that ecosystem management must address. Culture, values, and communities change at somewhat predictable, poorly predictable, or entirely unpredictable rates. Because many changes are less than somewhat predictable, ecosystem management needs a process to continually monitor and respond to perceptions of societal goals.

The societal expression of goals for ecosystem management will become more complex, diverse, and changeable in the future because of increases in:

- Number of consumers of ecosystem resources;
- Demand for political access to the policy process for ecosystem management;
- Range of societal tastes and preferences for ecosystem goods, services, and states, including intergenerational and even interspecies equity (Stone 1974);
- Ecosystem knowledge and public demand for access to ecosystem information; and
- Legal constraints to property rights.

This diversity of human perspectives, like biological diversity, promotes adaptability, prevents a single philosophy from domininating, and hedges against societal loss. Diversity is also assumed up to a point to increase adaptability to our changing world--of cultures, rural and national economies, and public employees.

Premise 4: In a society of diverse and sometimes discordant communities, too many goals or conflict over goals for ecosystem management may develop; some people may not get what they want. Ecosystem management goals expressed by global, national, regional, and local communities may not be compatible when applied to the same ecosystem. Goals may individually or collectively exceed the capacity of ecosystems. Goals of different communities may also be mutually exclusive. Societal conflicts must be sufficiently resolved so that ecosystem management can proceed with clarity of purpose.

One essential human need is for order and resolution to impose sense in the world. Society decides on ground rules (equity, fairness, respect for minorities) about interpersonal conduct. In this way, civic discourse (Shannon 1991) becomes established at multiple forums so that people resolve conflicts and, for the moment, restore societal order and the ecosystem contract. For the sake of societal order and clarity, personal goals defer to goal-setting by the public at large.

When the process of representative government is not perceived to satisfy the needs of some people, many strategies are available to decrease peoples' sense of unfulfillment or alienation and to increase satisfaction and trust. Society as a whole makes concessions to people in minority communities or to people who are incapable of representing themselves, such as future generations. An informed society is more likely to be able to retool through compromise, compensation, and alteration among individual, community, and societal goals.

Several approaches can be used to resolve conflict among communities. Approaches differ in the degree of openness in decision-making, the venue for the decision-making, and the assumptions about who is right or wrong and who is a winner and a loser (Amy 1987). Three approaches are:

- **Management by experts**. Civil service professionals have authority. As recognized experts, they decide how societal needs should be translated into public land management goals and practices. Various degrees of integration of information might be expected among resource interests depending on legal mandates. Management tends to be specific over small areas and general over large areas.

- **Management by prescription**. Courts, legislative bodies, and executive decrees establish the program of management based on the rule of law. Management tends to be prescriptive over large areas. This process relies on the expertise of lobbyists, lawyers, and politicians to solicit ecosystem experts to support their cases convincingly.

- **Management by collaboration**. Communities of common interest in an ecosystem but with dissimilar sets of values and needs from the ecosystem collaborate to establish binding site-specific goals through tradeoffs, compromise, and consensus. No one side in the issue is right by rule of law or by expert opinion. The process of goal-setting often includes a mediator or facilitator, lay people, experts, and litigators.

At present, no one approach predominates in the process of National Forest system decision-making for policy and management. The complexity of decision-making is, in part, the result of multiple societal scales at which decisions about ecosystem management are made and the premises under which the decisions are made.

Premise 5: Ecosystem management decisions benefit from societal goals that are clear, informed, and integrated, and that recognize that ecosystems are complex. Public debate and conflict reveal the spectrum of needs demanded from ecosystems. Being heard depends on access to policy processes, and access depends on the ability to acquire and organize resources for effective advancement such as lobbying and testifying. Legislative authority establishes a body of "policy-makers," whose composition is open to interested community members, professionally involved civil servants, and social and natural scientists. Policy-makers call on the general public, social scientists, and natural scientists to provide substantive information for integration into policy decisions about societal goals.

Policy-makers need evidence of the public preferences for ecosystem management. One tool for information gathering is public hearings at various geographic and governmental scales. Hearings depend on self-selection of interested individuals and communities; thus, bias is inherent. Individuals or communities with no awareness of or access to hearings are disenfranchised. Societal groups that do not have access to the public hearing process have opinions, even if the opinions remain unarticulated or unheard. Problems can result from not including them.

An important question for society is the extent to which policy-makers and society should attempt to consciously gather views from all communities, including groups not often heard. Social scientists use scientific methods to provide objective and unbiased societal evidence to policy-makers in two ways (Lasswell 1970): by analyzing the present expression and anticipating future expression of

societal needs, particularly among communities with no previous access to decision processes, and by estimating for society the present and future value of ecosystem products, services, and states that satisfy societal goals for ecosystem management.

Scientists provide society with information about the ecosystem structure, function, and compatibility with various sets of ecosystem goods, services, and states. Scientists encourage the public and policy-makers to reexamine goals and priorities in public land management (Hardin 1991). A task for scientists is to describe, analyze, and explain trends and emerging problems.

Effective scientists are often not only experts in their disciplines but also in influencing policy for managing public lands (Clark 1992). Rarely are these experts the only participants in policy-making, however. Their role is to discover knowledge and anticipate issues in management and society's needs (Lasswell 1970). Policy-makers and the public base decisions on scenario planning for predicting probable outcomes of future management. One scenario is usually the status quo projected into the future. Other versions reflect management for sets of demands for goods, services, and states advanced by various communities.

Land managers also require from policy-makers clear mandates to implement realistic goals. Mandates require the best available ecosystem and societal information, unimpeded communication between policy-makers and ecosystem managers, trust in ecosystem managers to exercise their professional expertise well, and recognition of the need for a flexible response to unpredictable events in the ecosystem (Clawson 1977, Koch and Kennedy 1991). When society does not invest adequately to acquire ecosystem information and to express clear goals, managers cannot be decisive and can lose the public's trust.

Premise 6: Policy-makers translate scientific information about ecosystems and societal goals into treaties, laws, government bureaucracies, planning, and budgets. Codification organizes land management into spatial and temporal patterns consistent with properties of ecosystems and with the goals of society. Society allocates rights to property ownership, use or extraction of resources and services, and acquisition of values through formal contracts among users and between present and future generations (Lichatowich 1992). Regulation is a political effort to enhance human well-being by providing reliable and efficient use of property, resources, services, and ecosystem values. Formal planning processes help ensure that management properly recognizes societal objectives and achieves the desired effects for society and ecosystems.

Regulation of rights prevents users from causing a net loss from private actions for individual welfare. Treaties, property rights, and use and extraction rights are inviolate under the terms and duration of societal contracts, and illegally taken rights must be restored. Government cannot withdraw rights from a holder without just and acceptable compensation to the holder of rights. For example, American government treaties with Native American nations have the full force of international treaties.

Ideally, bureaucracies are a means of streamlining communication processes: collecting information and having it flow to the proper levels of decision, so that tasks can be identified and assigned to those most qualified for carrying them out (Burch 1971). Bureaucracies require continual monitoring to ensure that they:

- Follow guidelines for generating, standardizing, conserving, and distributing information as needed to appropriate communities;

- Remove institutional barriers to implementing societal goals for ecosystem management;

- Reduce jurisdictional conflict in decision-making;

- Improve organization and technology for information generation, storage, and dissemination in decision processes;
- Delegate some responsibility for decisions away from centralized bureaucracies to land managers in local, peripheral settings; and
- Arrange for sufficient appropriations and manage them efficiently for implementing management.

Premise 7: However much people attempt to anticipate and control outcomes and effects, policy for ecosystem management will always be decided under conditions of uncertainty and ignorance. Science emphasizes probability and not certainty (Lasswell 1970). This emphasis may run counter to other existing societal dogmas that insist on predeterminism of the future. Some communities may not wish to accept uncertainty in the societal and scientific frameworks for ecosystem management, thereby creating an opportunity for societal discord. Unfortunately, policy-makers often interpret the lack of certainty in science as justification for inaction (Sample 1991). Such justification is deemed inappropriate for delaying actions to curb human activities that effect global warming, ozone depletion, and depletion of fossil fuels (Ludwig et al. 1993).

People do not perceive all of the diversity, complexity, and changing nature of society and ecosystems around them. Thus, information is inevitably inadequate for complete identification of peoples' needs and opportunities to fulfill them. Scientists and bureaucrats may not be able (or may choose not) to manage and use information about societal and ecosystem responses. Policy-makers and the public may not be able (or may choose not) to receive and interpret information. Incomplete or mismanaged information leads to dysfunction in ecosystem management; as a result, people easily corrupt or maladapt policy processes (see page 39).

Monitoring by scientists and other interested communities provides a means to draw attention to ignorance and uncertainty. Lack of investment in scientific monitoring subverts the credibility and authority of science and ecosystem management. Reactive monitoring on the part of disaffected communities (see for example Morrison 1990) may produce better information and discredit policy-makers and government agencies entrusted with ecosystem management.

Policy-makers and ecosystem managers must understand and manage types of responses to uncertainty and ignorance (Ravetz 1986) to their advantage. Faber et al. (1992) provide a taxonomy of ignorance (see fig. III-3). If people remain unaware of their ignorance ("closed ignorance"), they perceive no need for additional information and research. Experiences of surprise or shock (Brooks 1986) can provide a sudden awareness of previously closed ignorance. Unexpected or discontinuous enlightenment in societal perceptions can promote uneven evolution in societal thought, technology, policy, and institutions. Precipitous establishment of an Eastside Forest Health Panel to rapidly assemble insights and contexts for ecosystem management in eastern Oregon and Washington is evidence of jolts in awareness of imperfect ecosystem knowledge and land management practices of the past.

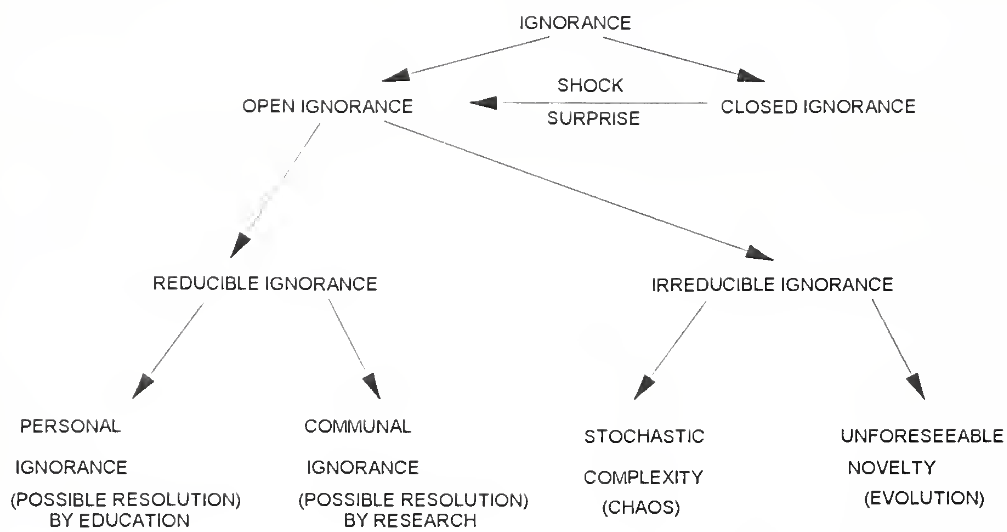


Figure III-3. Taxonomy of ignorance after Faber et al. (1992) and Ravetz (1986).

Recognition of ignorance after the experience of surprise leads to "open ignorance," where ignorance recognizes itself and arrives at the awareness of the need for knowledge (Ravetz 1986). Attempts to overcome ignorance sometimes reduce personal or collective ignorance. Other attempts might fail. "Irreducible ignorance" cannot be overcome; and certainty cannot be achieved because of chaos and novelty (Faber et al. 1992), which defy human cognitive capacity. Limitations to overcoming ignorance are grounds for human humility. Recognition of the limits of knowledge and certainty promotes management that plans for the unforeseeable, with enough options and flexibility to change course in management direction quickly.

Premise 8: Unexpected ecosystem events and shifts in societal demands for ecosystem products require changes in societal institutions, and these changes will bring changes to society. Policy-makers make deliberate choices whether to respond to surprises in the ecosystem or in society. Policy-makers also choose to respond effectively or ineffectively. Intentions without actions are not an effective response; policy rhetoric and subsequent action must be consistent.

Without timely and incisive response to changes, policy-makers at whatever scale quickly lose credibility with society. Society can overreact when ecosystem states and societal values are changing rapidly or unexpectedly, public policy is timid, and land managerial mandates are vague (Quigley 1992). Investment in ecosystem science, ecosystem management personnel, and market research about society's needs must follow policy rhetoric advocating sustainable-ecosystem management.

Society demands to know how much ecosystem management costs and what are its future risks and benefits. People are certain to have different attitudes toward investing and incurring risk to achieve admittedly uncertain future net benefits through ecosystem management (Montgomery, vol. III). In an era of high national deficits and societal demands to cut Federal expenditures, potentially high startup costs for achieving ecosystem sustainability may meet with public disapproval and political resistance. Other citizens may recognize direct benefits that ecosystem management can accomplish or immediate and long-term consequences of failure to manage. Society must recognize that achieving desired ecosystem conditions will likely require public investment. Such

investments must, therefore, compete with other demands for scarce public resources. As with any investment decision, however, inaction or insufficient funding for ecosystem management may entail even greater future costs and risks, and result in fewer future options and lower net benefits for society.

Policy-makers are obligated to society to estimate and make known costs, risks, and net benefits to society of ecosystem management as explicitly and honestly as possible. They must also decide and justify allocations to various communities of the costs and risks needed to obtain the new mix of ecosystem resource benefits under ecosystem management for sustainability (Odum 1992). Changes in composition and allocation of ecosystem resources (who pays, who benefits, what, how much, and when) shift power both within and among communities. Local communities that depend directly on ecosystem resources for livelihoods but do not control those resources are especially vulnerable to shifts in power.

Policy decisions determine issues of justice and equity in ecosystem management. Because most Americans live in cities, demographic and economic power resides in urban areas. Society makes decisions about equity in policy centers that may lie in or outside of eastern Oregon and Washington. Lack of access by rural communities to decision-making and perception of no gain from ecosystem management for local rural communities may create alienation and new sources of societal conflict. Policy-makers need to maximize recognition of gain by both urban and rural communities, although the type and degree of gain for various communities is likely to be different (Smith, vol. III).

Effects of changes on society at multiple spatial scales resulting from changing resource production in local ecosystems are poorly understood (Machlis et al. 1990). Efforts to avert ecosystem catastrophe by implementing ecosystem management must not unwittingly initiate undesirable societal change. The rate of societal change induced by changes in the availability and allocation of ecosystem resources might exceed the thresholds of communities, particularly resource-dependent communities, to cope with and absorb change (Machlis and Force 1988). Societal expenditures to mitigate cultural and community dislocation and assist coping with resultant changes (by job training, loans for small-business start-ups) must be weighed against costs of dislocation in communities exhibiting stress (crime, alcoholism, child abuse) induced by changes in the conditions of ecosystem resources.

Conclusion

To include more societal processes in ecosystem management, people themselves must integrate social and natural science research and resulting societal processes with knowledge of natural patterns and processes of forest ecosystems. The premises form the framework for an understanding of the origins of objectives for ecosystem management, a basis for evaluating the breadth and durability of popular support for particular objectives, and a basis for evaluating effects on society from ecosystem management practices.

Developing a theory and appropriate practice of land management for ecosystem sustainability in eastern Oregon and Washington forests demands that people understand how people regard, affect, and are affected by ecosystems (fig. III-4). Our framework reflects the fact that people are an inseparable part of forest ecosystems. The process of defining ecosystem management objectives is a societal process; sustainable management requires social science expertise combined with knowledge of ecological interactions. Societal interactions, along with science and technology, form the policy process and translate it into ecosystem management objectives and practices that society finds acceptable.

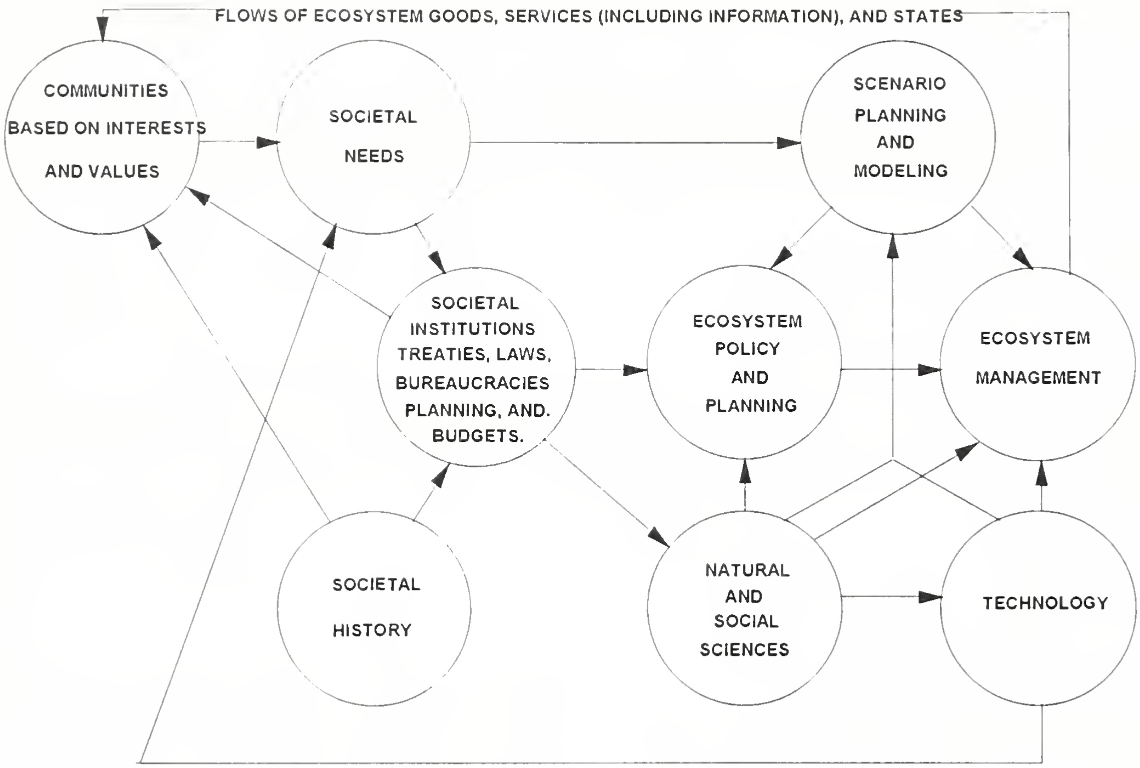


Figure III-4. The role of society in ecosystem management. All unlabeled arrows show direction of information flows.

Science and Technology in Ecosystem Management

Both social and natural science need to be integral to ecosystem management. Science currently appears to be oversold as the cure for environmental problems, and many people believe that science and technology can overcome whatever has or can go wrong. Ecosystem managers must understand the limits of science and place science in the broader context of all activities leading to ecosystem management.

Science can describe constraints on ecosystem management, but it cannot specify management actions in precise detail. Much is known about ecosystems and their components, but ecosystem management must be based on the integration of a wide array of natural and social science disciplines. We have tried to avoid approaching ecosystem management from the perspective of a single discipline, and propose the following science premises as an integrated basis for ecosystem management:

Premise 1. Natural sciences recognize people as part of the ecosystem; social sciences recognize biological and physical constraints. A wide variety of human influences and unpredictable events compound each biological issue. "Health" and "sustainability" are human concepts, and people's definitions may be very different. Placing all responsibility for forest health on the forest, its processes, and the inadequacy of forest science ignores the triggering causes of forest health decline: society's failure to understand the limits under which ecosystems produce goods, services, and states for society--and society's failure to understand itself. Analyzing the options available to society for directing its own behavior to promote ecosystem health and sustainability is as important as research in natural science and land management. Changes in economic behavior, societal institutions, and the understanding and use of ecosystem information, psychology, and philosophy are needed to realize sustainable-ecosystem management. How

people, especially the people entrusted with land management, contributed to declines in forest health, through imperfect understanding of societal and ecosystem processes, unintended consequences, and changing social objectives must be analyzed. And how people and their institutions will have to change to attain ecosystem sustainability must be recognized.

People make choices about their use of scarce resources, and these demands are measurable and interpretable. The study of these choices and demands through surveys and other techniques provides an initial estimate of how society would like ecosystem management to proceed, and can help planners formulate an initial set of options for goals for ecosystem management. The actual choices must be made through political mechanisms, however. Distinguishing between the study of society's attitudes and behaviors, and the actual actions of society is important.

Physical and biological laws determine what is possible. Future ecosystem conditions should be forecast based on general rules derived from fundamental theories and laws of science. The idea is to have robust guidelines that specify when it is likely that an ecosystem is being used beyond its sustainable capacity.

We are only beginning to identify the rules that may be useful in ecosystem management. The extreme example may be constraints imposed by physical laws that are impossible to avoid: no management action is going to repeal the law of gravity, and any management plan that implied an outcome that violated this law could easily be rejected. On the other hand, this law gives no positive advice on how to manage an ecosystem. So we need principles for which violations are more or less obvious and which give positive hints on how to manage.

- **Conservation of matter and energy.** The laws of conservation of matter and energy set up an accounting framework for the physics and chemistry of ecosystem processes. But what is important to realize is that the **dynamics** of matter and energy are contained in the components of an ecosystem, and that the matter and energy contained within any ecosystem are finite.

- **Laws of thermodynamics.** The laws of thermodynamics play an important role in ecology in that they set limits on the efficiency of energy transfer. At each step of energy transfer within food chains, the efficiency is only about 10 to 20%.

- **Fundamental theorem of natural selection.** The ability of plants and animals to adapt to change depends on diversity and natural selection.

- **Limitations imposed by imperfect information.** Finally, any management and assessment of the ecosystem and of social desires is going to rely on sampled data. The laws of statistics provide guidelines as to whether and when we can actually collect enough data to be able to make reasonable statements about ecosystems. That is, if we conceive of ecosystem management as the setting and testing of a hypothesis, are we more concerned about accepting the hypothesis when we should have rejected it or about rejecting the hypothesis when we should have accepted it?

This limited list certainly does not imply that all other scientific knowledge is not useful (for example, landscape ecology, silviculture, political science); it only implies that their underlying assumptions must be continually questioned.

Premise 2. Science has roles as both forecaster and conscience. People often say that forest management must be based on scientific principles. The range of possible uses of science can be described as two polar positions: science as forecaster and science as conscience: we believe that both roles are important to ecosystem management.

First, we must distinguish between predicting and forecasting. In our use, forecasting means to specify changes in ecosystem variables into the future. Forecasting may be based on current actual conditions or may be done as "what-if" scenario analyses. We use prediction as a much more general activity that includes hypothesis testing without necessarily referring to the future. Prediction and forecasting need not imply use of complex computer models; they may also be based on simple conceptual models.

In its forecasting role, science provides the machinery for predicting the future state of an ecosystem, given knowledge of its present state and any management practices applied to it. For ecosystem forecasting to be possible, we must have a theory for defining ecosystem components and a theory of the dynamics among those components, as well as the data necessary to estimate boundary conditions and parameters (see premise 4).

Forecasting of natural resource conditions has often failed, even for relatively simple systems. For example, models that predict the sizes of fish populations have been developed in great detail for many commercially important species. These models appeared to be successful for many years, but recently they have failed to forecast serious declines in fish populations. The fundamental dynamic assumptions of these models, the data used to parameterize them, and the actual results have come under severe criticism (Hall 1988, Larkin 1977).

A major reason that ecology does not forecast well is that most causes have multiple effects and most effects have multiple causes. Thus, even when a correct prediction is made, it may be sheer coincidence. For example, a major program of screw worm eradication introduced millions of sterile males into the population, which then declined as predicted. The population cycles anyway, however, so the result may have been coincidence.

In practice, science often seems to play the role of a kind of conscience. In various ways, science cautions society not to overdo exploitation. Science makes people continuously aware that any natural system pushed too hard will collapse, even if the exact mechanism or timing of such collapse is not understood.

Premise 3. The structure and use of science limits its application for ecosystem management.

Limitations include:

- A staggering number of science disciplines are relevant to ecosystem management.
- Disciplines have become narrow and fragmented.
- Integration of disciplines is difficult because of differing assumptions, language, and scale.
- Scientific models support but cannot replace judgment.
- Science cannot forecast specific outcomes for management actions, only ranges of outcomes.

For example, gap models that address mixed species stands have been produced (Shugart 1984), usually stochastic models, reflecting the fundamental uncertainty of the species replacement process (Horn 1975). This uncertainty makes the models realistic, but when the models run many times, they exhibit an extraordinary range of possible behavior (Kiester and Ladd 1991) and would not be useful for forecasting particular situations.

Ecosystem management is more like trying to manage a stock portfolio than an oil refinery: the value of stocks is uncertain, but an oil refinery can be made to produce predictable outputs. Thus,

the very process of setting goals must consider the uncertainty in ecosystems. The practice of ecosystem management must develop tools for managing uncertainty, including forms of hedging and arbitrage. The processes of an ecosystem are not **completely** unpredictable, however, and management can be tailored for each circumstance.

An advantage of recognizing limited predictability in goal setting is that expectations for what managers can actually accomplish are more realistic, and managers are much less likely to fail. So an important part of viewing the world as uncertain is that managers must "manage" the expectations of those who are concerned with the results of ecosystem management through good information and frequent interactions. And they must ensure that the public understands that the target for ecosystem management is more like a cloud than like a point. Thus, active communication of clear information has an vital role in ecosystem management.

Premise 4. Ecosystems are artificial constructs and therefore must be selected and classified with caution. In the absence of a strong theory of ecosystem evolution, ecology or economics, the definition of an ecosystem is a human construct, subject to wide variation depending on the background and perspective of the definer. Identifying examples of an ecosystem depends on judgment as to what actually constitutes an example. Although we have no set criteria for defining ecosystems, we can develop criteria to define them operationally to help set and achieve management goals. We do have a strong and complex theory about the constitution of species and how they are created. Ecosystem management thus recognizes species as important units because they are understood to be important units in the process of evolution. Aggregate entities above species (genera, families, and so on) are artificial and must always be considered working hypotheses.

We regard ecosystem management as an experiment, in which both the identification of ecosystem components and their dynamics are up for investigation. Results of such experiments not only imply something about changes in the components of the ecosystem, but also about the usefulness of considering that those components exist at all.

To be able to forecast, we must identify the ecosystem variables we are interested in forecasting and then devise a model forecast for those variables. The problem is that how to pick those variables is not obvious. Many ecosystem variables, such as chemical elements and species, have well-developed theoretical bases which tell us how to identify and separate different examples of the variables. For example, the atomic theory of the elements tells us how to tell two elements apart and when to decide that two samples are of the same element. The theory of evolution gives us the same abilities with regard to species, but many other variables that can be used to describe ecosystems are the result of artificial classifications and do not have a theoretical basis. These classifications are built for the purpose of doing some work, but they do not provide us with a way of resolving conflicts between two different systems of classifications.

One way of making clear the issue of the difference between variables with a theoretical basis and variables that are artificial constructs is to consider what may be called the "problem of the environment." Pick an individual animal and then ask how we describe its environment. The answer is not obvious because the environment has no genetics, unlike animals and plants. That is, no theory tells us how to account for similarities and differences of different examples of the components of this animal's environment. Genetics does allow us to account for the similarities and differences between the animal we have chosen and any other. Ecosystem management must confront the problem of the environment head on.

An important class of artificial creation and limitation of ecosystem variables occurs when managers define a unit of management and then treat that unit so that it is guaranteed to be identifiably different from those units that surround it. Perhaps the extreme example would be a clearcut in an uneven-aged mixed species forest that is replanted with a single species. No way of subdividing the

forest into stands is obvious here, but the process of clearcutting and replanting transforms the forest into a set of stands. Clearly, this form of false definition produces identifiable entities, but it also severely reduces the possibility of alternative definitions.

Premise 5. Diversity is essential to adaptability. The concept of diversity is central to our framework, and it extends across all system components, both social and biological. Benefits of increased diversity are assumed to be increased adaptability to our changing world--of organisms, rural and national economies, and management agencies.

The "fundamental theorem of natural selection" provides a basic biological constraint on ecosystem management (Fisher 1930). We consider the theorem in a more general way (Lewontin 1970) to say that the rate of adaptive change in a system is proportional to the amount of variation of those systems. This theorem establishes the importance of biological diversity per se in ecosystem management.

If we wish to consider the dynamics of the elements of diversity--that is, the individual species--we may use the mathematical theory of demography developed by Lotka and Leslie (in Keyfitz 1968). This theory provides the bookkeeping framework for following individuals within relatively well-defined populations; for human populations, it works very well (Keyfitz 1968). Using life tables to understand population dynamics for other species, rarely works well, in part, for lack of data. If they worked well, we would have a theory that forecast for individual populations, but we have no such theory. Thus, we can only provide qualitative estimates for such statistics as minimum viable population. Clearly, this approach will be applied to only a very few species in any ecosystem, and the process by which those few species are chosen must reflect the total framework for ecosystem management. What must be considered is the ecosystem as a whole, with no special pleading for particular species.

Premise 6. Ecosystem patterns and processes appear, and must be studied, at different geographic and time scales; reconciling these different scales is difficult. For example, many processes occur at scales of individual plants and animals. The oxygen concentration around the root of a pine tree determines the extent of associative nitrogen fixation (Bormann et al. 1993), and cumulative nitrogen fixation influences the ecosystem's ability to capture solar energy. Evolution also controls patterns and processes of ecosystems at greatly expanded scales of time and space, however, and needs to be considered for ecosystem management. The study of evolution is both the study of the history of life on earth and of the processes by which evolution occurs. Considering the history of evolution leads to a broader scale of time and space than is customary in forest management. In conservation biology, considering large scales of time and space is known as the "coarse filter" approach (Hunter et al. 1988, Shafer 1990).

Premise 7. Local conditions may override or obscure general patterns and processes; the general may not contain the particular. Often, theories that are generally true prove difficult to apply in specific instances, where the particular conditions and history of a site may dominate over any general principles. We recognize that any general philosophy, theories, or models cannot be easily and directly applied to each particular case in ecosystem management. As individual decisions are made in a given management activity, those decisions must be measured by how well they approximate the general theory. The approximation may be relatively poor, but at least we will know in what way we are failing and can work to do better.

Because general rules may not apply to particular cases, reasoned **judgment** must be recognized as a crucial part of ecosystem management. Ecosystem management must be up front about the role of judgment. In an attempt to be scientific, forest managers have often attempted to replace judgment with a theory or a model; the theory or model is an absolutely necessary component of decisionmaking, but judgment is still required.

Premise 8. Ecosystem science at large scales relies on ecosystem management for empirical evidence. Ecosystem science has been hindered by the difficulty and expense of large-scale experiments to understand responses of ecosystems. Watershed studies, the best attempt at this kind of experiment, proved expensive and have declined in number. Without experimental evidence at the temporal and spatial scale of management, the theory of ecosystem management will have to be weakly based on untested hypotheses drawn from observational data and experimental evidence from other scales.

Management of ecosystems could be altered to provide experimental evidence to test ecosystem theory if management:

- Is laid out in an experimental design;
- Is changed from the concept of "best" practices to allow several treatments to be compared;
- Recognizes that controls are impossible at broad scales because of inherent complexity; and
- Includes standard, smaller scale, more controlled experiments nested within large-scale experiments (that is management).

Science and Technology

Technology is often seen as a manifestation of science, but it is better considered a manifestation of the interaction of society and science. The multiple, and frequently unexpected, effects of technology on society are similar to those of science, but they are often more striking. Changes in technology, especially information technology, can change societal demands, allowing people to recognize that they have a wide range of choices. Technology can directly affect the availability of options by reducing costs and providing substitutes. Virtually all technology, however, has unexpected side effects that may be either beneficial or detrimental to a wider set of goals than the goal the technology was originally designed for. The net effect may be to change society's attitude toward technology as a whole. Although the effects on the natural ecosystem of a given technology may be direct if unanticipated, its effects on society may be hard to trace. Changes in people's attitudes toward technology must be incorporated into ecosystem management.

MANAGEMENT SYSTEM FUNDAMENTALS

Organization of science, technology, and people in coordinated systems has been studied for many decades as the discipline of "management science" (Taylor 1911). The lacing model described in section I (pages 17-19), is partly based on concepts from this field. Management science focuses on the behavior of systems--a regularly interacting group of items forming a uniform whole. Management systems coordinate the activities of defining goals, planning, implementing, and monitoring. Understanding management systems helps understand both why forestry has reached its present condition and how ecosystem management can increase effectiveness.

Ecosystem management includes social and natural science and technology. It consists of several different kinds of activities: policy, analysis and planning, operations, and consideration of biological and physical constraints:

- Policy defines broad goals, both for what society wants and tradeoffs among conflicting wants. For Federal lands, representatives of the public traditionally have set management objectives directly or indirectly through the political process.

- Analysis and planning activities are necessary in complex land management systems to allow policy-makers to determine tradeoffs among conflicting goals and to ensure the correct operations are done at the correct time and place to meet the landowners' objectives.

- Operational activities use the infrastructure to mimic, prevent, allow, or replicate various ecosystem patterns and processes to achieve management goals. Correct timing, type, and location of each operation is defined through planning. Operations are directed by either public employees or independent contractors.

- Ecosystem management differs from managing commodity flows. One difference is that obtaining goods and services from the ecosystem changes the ecosystem itself, and the possibility of this change constrains management.

Infrastructure: professional and technical people, equipment, communication and transportation systems, and markets.

Coordination Systems

The idea that systems to coordinate political, planning, or operational activities could be means to efficiency began about 1900 (Taylor 1911, Wilson 1887). Before then, such systems were regarded separately, with only haphazard coordination among them; and coordination systems were regarded as means of power.

Management became a science when people believed that a "correct way" existed for coordinating scientific and technical fields--and the correct way could be determined through scientific methods. The study of ways of coordinating is presently done under a variety of names--management science, systems engineering, organizational theory, systems approach, systems analysis, and planning (Ackoff 1974, Bennis 1966, Blau and Schoenherr 1971, Cleland and King 1968, Dieter 1991, Kranzberg 1984, Roberts 1979, Simon 1960). Public and private organizations in the United States adopted the new management concepts in the early 20th century. The greater organizational efficiency helped this country gain a global advantage in industry, conservation, and standard of living (Reich 1983).

By the 1950s, the study of systems had incorporated consideration of uncertainty and human judgment, so a single "correct way" was replaced with effectiveness in achieving objectives. Very effective management systems were developed by using a concept of "total quality control" (Feigenbaum 1951, 1983).

Several factors that keep organizations from becoming more effective have been identified:

- Insufficient natural, political, social, and economic science knowledge, or technology;
- Insufficient communication and information acquisition, processing, and storing techniques;
- Insufficient trust in and understanding of systems;
- Bureaucratic resistance;
- Insufficient motivation because of misdirected focus on commodities; and
- Insufficient understanding of nature as a system to be worked with rather than commanded.

Management systems incorporating the latest knowledge of systems theory were shown to be effective in both industrial and service organizations in Japan after World War II (Deming 1982). Present global competition in the private sector requires that private management systems become more effective throughout the world (Reich 1983). At the same time, the increasing, more environmentally aware population is making demands on ecosystems that require people to manage more effectively.

Modern management systems allow an organization to function in an "organic" way, avoiding the mechanistic rigor often associated with early management systems. Ecosystem management is well suited for these modern systems became the focus is on achieving and maintaining dynamic patterns and processes in ecosystems and society.

Management Systems Behavior

Management systems are successful to the extent that the actual outcomes of management operations are the expected and desired ones. Increasingly correct policies and planning require understanding the behavior of all scientific and technical components so their responses to various management operations can be predicted. To the extent that results of management operations can be predicted correctly, realistic goals and tradeoffs can be established and operations planned and implemented to achieve the goals.

Incorrect understanding of any one system component usually causes a "dysfunctional" management system--one that cannot achieve the stated objectives, although it will achieve other unexpected outcomes. For example, an incorrect assumption that all forest fires in eastern Washington and Oregon were harmful resulted in the incorrect projection that the forest would be more stable and produce more benefits if all fires were stopped. Fewer desired goods and services were produced, and the ecosystem state that developed had overcrowded, small trees, insect infestations, and the potential for uncontrollably large fires.

> Dysfunctional system: management results are not the same as the goals because of one or more large errors somewhere in the system.

An inefficient system attempts to achieve the objective by correcting errors with some operation or procedure. This corrective action often does not correct the original error; instead, it just attempts to compensate for it. Such compensations may cover up or confuse the original error in the projection, and sometimes achieve the original goal. Almost always though, these compensations do not achieve the stated objectives of management with the least possible time and effort and therefore are "inefficient." For example, when suppression of fires created overly dense stands, the trees became susceptible to insect attacks and uncontrollable fires. The "ad hoc, downstream compensation" was to control insects through chemical spraying programs and to increase fire prevention efforts.

Inefficient system: in an effort to achieve the desired goal, an adjustment for an error creates another error which merely compensates for the first error.

Forest land management systems have historically been inefficient because of failure to integrate natural and social sciences, the existing ecosystem conditions, and the (until recently) limited technology allowing communication among policy-makers, analyzers, planners, and operators. Much of the early success in settling American forestlands was because individuals took the initiative and broke existing rules and laws (Steen 1976)--accomplishing the "spirit" of laws by the equivalent of ad hoc, downstream compensations. Inefficient management--and the breaking of rules to accomplish the objectives--has been accepted as a necessary part of management, under the names of "hip shooting" and "quick fix" (Feigenbaum 1983). The many challenges to a previously inefficient system have produced a relatively dysfunctional one. The intended purposes--multiple use, sustained yield, timber production, or even habitat protection--remain unfulfilled.

Dysfunctional or inefficient organizations can only be corrected when the cause of a management error is identified and corrected at its source (Feigenbaum 1983). Intensive efforts, including managerial reorganization or scientific research, directed at the wrong part of the system will not improve it.

Top-Down and Bottom-Up Processes

The context of the management system often has multiple conflicting influences. The resolution of these conflicts, through decisions on tradeoffs, often start as top-down instructions. In managing large, complex systems, determining which goals are achievable--and with what tradeoffs--is difficult. Anticipating--and therefore planning--all outcomes when designing a complex system is not even possible, especially in ecosystem management, which has many unpredictable elements. Attempts to plan and control outputs through management may work for simple production systems through a top-down management pyramid, where expected procedures and outputs are described at the top and expanded downward through a bureaucracy. A top-down system leaves little room for analysis by operations people and reduces their job satisfaction. Because the system has errors, analysts and operations people will use their creativity to produce ad hoc, downstream compensations. Top-down output planning at the U.S. Forest Service regional scale for the flow of timber from various National Forests has proved to be inefficient (Johnson 1992). Such top-down planning also does not allow flexibility in changing operations to correct errors or to achieve changed societal objectives (Reich 1983).

Only by physically working with the resources at the operational scale can people judge the feasibility, effort, and tradeoffs of achieving various objectives. Bottom-up knowledge must flow to the decision-makers at broader geographic scales in an iterative process, so the correct balance between what is desired, what is achievable, and what are the costs, benefits, and tradeoffs can be made. Four strategies help to integrate top-down and bottom-up aspects of management :

- **Manage simultaneously at multiple geographical scales.** Goals at the national scale can be managed for when regional- and local-scale feedbacks on tradeoffs and feasibilities are considered. Local goals can be managed for when the regional and national context is considered. This multiscale approach was the basis for the lacing model. Recent and impending advances in public involvement and technology may make the flow of information more effective in the future.

- **Avoid micromangement.** Especially in ecosystem management, specific techniques to achieve objectives will vary in time and space with biological, social, and technological conditions and knowledge. Therefore, management decisions must be made at the appropriate scale. Although the specific goal of managing for certain ecosystem goods, services, and states needs to be broadly stated, the techniques for achieving them will differ dramatically. In this way, ecosystem management will have a "portfolio" approach to management, with each local area managed flexibly to achieve a goal (Oliver 1991, Gottfried 1991). A system can remain efficient if the management system is flexible enough to change techniques for achieving goals when conditions change (Reich 1983).

- **Manage the management system.** Ecosystem management can only be maintained if the management system remains efficient. If the system contains many ad hoc, downstream compensations, the compensations may inhibit efficient management if conditions change. A primary focus of management, therefore, is designing and maintaining the management system; if it is designed and working efficiently, by definition, it will produce the desired (and expected) output.

- **Keep policy-makers informed.** To ensure realistic decisions about the consequences, tradeoffs, and effort spent to achieve various stated objectives, policy-makers along with society, managers, and scientists must communicate and inform each other. This feedback requires incorporation of natural and social science, technology, existing conditions, and infrastructure into the decision process. Tradeoffs can be further incorporated into legislation by setting priorities for possibly conflicting objectives or limited funds. Further feedback can occur with managing as an experiment, discussed earlier.

DEFINITION OF ECOSYSTEM SUSTAINABILITY AS A BASIS FOR MANAGEMENT

The most important concept associated with ecosystem management is sustainability. Our definition of sustainability for practical ecosystem management:

- Contains the idea of a continuing balance, where society obtains a desired yield of goods, services, and states from an ecosystem in the present without damaging the ecosystem's capacity to produce future goods, services, and states for society;
- Leads to a method for making a quantitative, objective assessment of sustainability for producing very different ecosystem products from very different ecosystems over varying periods; and
- Implies that many ecosystems require remedial management to restore them so that they can sustainably produce ecosystem goods, services, and states for society.

A practical system of ecosystem management comes to terms with continually conflicting and changing values of society. To change the management system, people must change the way that society makes decisions about the goods, services, and states that it demands from ecosystems. Under ecosystem management, society must avoid optimizing products from the ecosystem in the short term. Instead, management will focus on the conditions necessary to produce a set of goods, services, and states sustainably rather than on the goods, services, and states themselves. Achieving desired future condition for an ecosystem likely places constraints on the types, combinations, and quantities of ecosystem products obtained. Our methods for assessing sustainability and efficiency of ecosystem management treats the problem of ensuring that an ecosystem can deliver as yet unspecified and even unknown ecosystem products in the future.

We suggest that relating societal demands for ecosystem products to the effects that these demands have on the sustainability of the ecosystem is essential. We propose a calculation procedure based on theoretically simple measures of ecosystem capacity to deliver each good, service, and state to society in a sustainable manner. We introduce two units: the **Pinchot Standard** and the **Pinchot Efficiency**. The Pinchot Standard measures the sustainability of the chosen ecosystem goods, services, and states to society. We derived a measure, called the Pinchot Efficiency, that increases when more variety and greater amounts are sustainably produced from a fixed land area. These two units give focus and direction to the inevitable societal debates about management goals, appropriate ecosystem products, and amounts of products when ecosystem sustainability is the principle objective of management.

Three steps are required for calculating sustainability:

1. Select candidate goods, services, and states desired by society;
2. Determine ecosystem patterns and processes thought to be needed for the desired goods, services, and states; and
3. Jointly evaluate and set priorities among societal demands and ecosystem patterns and processes.

A simplified way of considering the problem of ecosystem management for sustainability is shown in fig. III-5. Although many possible goods, services, and states could be wanted from the ecosystem, some constraint is considered necessary in selecting those actually chosen. This constraint is based on the requirement that managing the ecosystem to achieve these goods, services, and states will not impair its capacity to continue to provide them in the future.

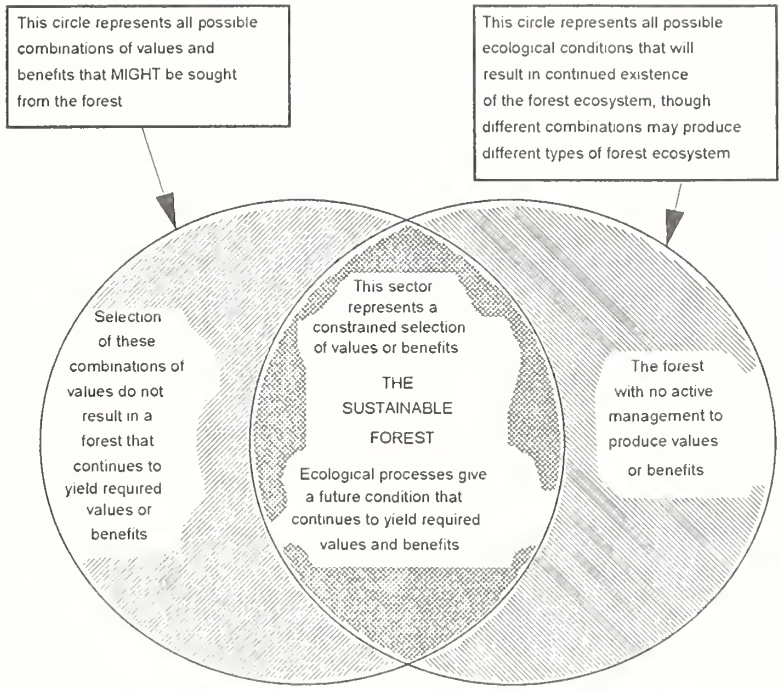


Figure III-5. Achieving a sustainable ecosystem may require some constraint in selecting the ecosystem goods, services, and states that society expects from an ecosystem. Constraint in selection ensures continued production of particular values. Ecosystem management may also include the requirement for managing future options for change, as a means of responding to changes in societal preferences.

Step 1: Select Candidate Goods, Services, and States Desired by Society

To begin the process of quantifying sustainability, I is the set of all goods, services, and states that people could desire from an ecosystem. The set has n different elements, which we index by $i = 1$ *to* n. Further, the set K contains all of the different communities of interest in society that have desires as to which goods, services, and states the ecosystem should produce. The set has m different elements which we index by $k = 1$ *to* m. X is the matrix of the amounts of each ecosystem good, service, and state desired by each community of interest. An individual element of this matrix $X_{i,k}$ is the amount of good, service, or state i desired by each community k. Some communities of interest may, of course, request the same quantities of given goods, services, and states as other communities of interest. For any particular ecosystem, the first task is to decide which individual $X_{i,k}$ terms are mutually compatible and possible to attain. This step is likely to be extended and complex where national, regional, and local objectives must be balanced. To do this, society (or its appointed representatives) chooses a subset of I called J, which are those ecosystem goods, services, and states that are possible and compatible for a given ecosystem. The subset J has p different elements and is indexed by $j = 1$ *to* p. Of course, $p \leq n$. For each of these elements, an amount x_j is determined that represents the amount of j that society chooses as a candidate value for the ecosystem to produce. These x_j are the first iteration in the process that ultimately determines the values that constitute management objectives.

Defining any dependencies among the various x_j terms for different ecosystem products is also important. Dependencies may be economic; for example, tourism depends on an infrastructure of roads, water, and sewer systems. Some values of x_j are not required at the same place all the time.

Step 2: Determine Ecosystem Patterns and Processes Thought To Be Needed for the Desired Goods, Services, and States

The second step in calculating sustainability is to identify those ecosystem processes that determine a given good, service, or state and are affected by that production. Thus, corresponding to the matrix X is a matrix Y. Each element $Y_{j,k}$ stands for an ecosystem process that supports the corresponding $X_{j,k}$ and is affected by that activity. The individual $Y_{j,k}$ may overlap a great deal because many similar ecosystem processes are often required for quite different goods, services, and states. Further, corresponding to the x_j are a set of p processes y_j that are the processes necessary to maintain the x_j. That is, each y_j is that collection of ecosystem processes that are necessary to maintain the output amount x_j of good, service, or state j.

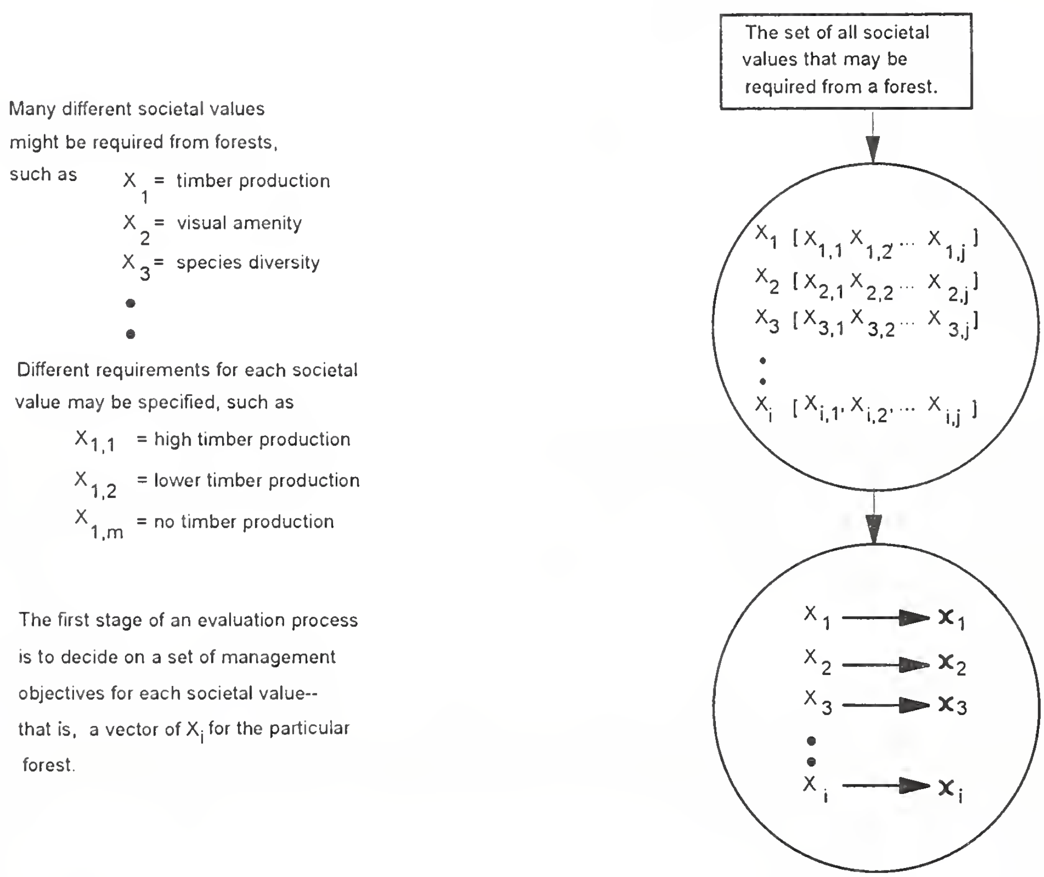


Figure III-6. A set of production quantities for each ecosystem product are selected.

The y_j must be sufficient for ecosystem management to ensure continued ecosystem patterns and processes for a future condition that continues to yield a set of certain ecosystem products x_j. The individual y_j may be subject to both natural events and management actions. We emphasize that because of the overlap between the different y_j, many dependencies exist between them. To begin with, we have an imperfect understanding of patterns and processes and hence of the dependencies. As knowledge of the ecosystem increases, our understanding of the dependencies between the y_j are updated and refined.

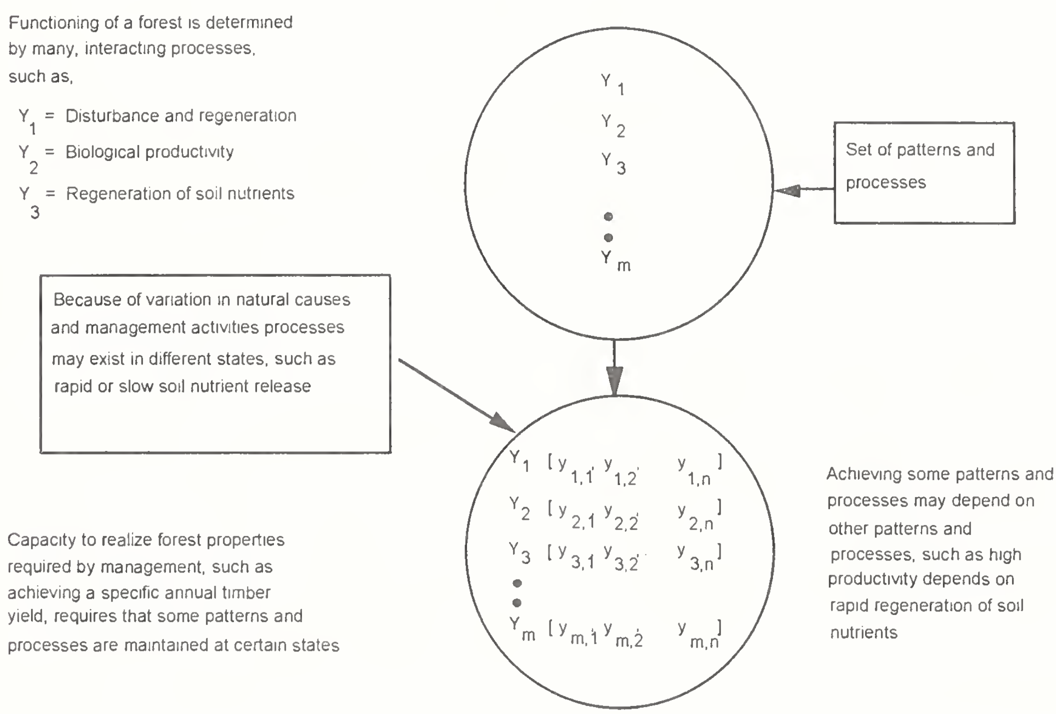


Figure III-7. Ecosystem patterns and processes required to achieve selected goals.

Step 3: Jointly Evaluate and Set Priorities Among Societal Demands and Ecosystem Processes

The third step in the process is to revise the x_j based on an analysis of the y_j. This process is one of determining and applying the constraints on the ecosystem such as we sketched earlier. This limits the elements of the value matrix, X, to those consistent with the process matrix, Y. Our first set of x_j may not have accurately reflected what society desires or may be based on an unrealistic understanding of ecosystem function. Iteration between determining what society desires and what is ecologically sustainable given our current understanding of the ecosystem must be continual. A

change in either desires or understanding requires a change in our calculation.

The selection of the present x_j values determines the future condition of the ecosystem in terms of the specified values. Some choices may destroy or seriously degrade the ecosystem for those or other values. For example, clearcutting over a large area with no replanting and no effective natural regeneration might maintain the yield of required x_j for a specified period. Such management actions, however, which are deleterious to the ecosystem itself, are represented in the left hand sector of the set of all possible management objectives (fig. III-8). The intersection of the set of $X_{i,k}$ and the set of $Y_{i,k}$ represents the condition of sustainability.

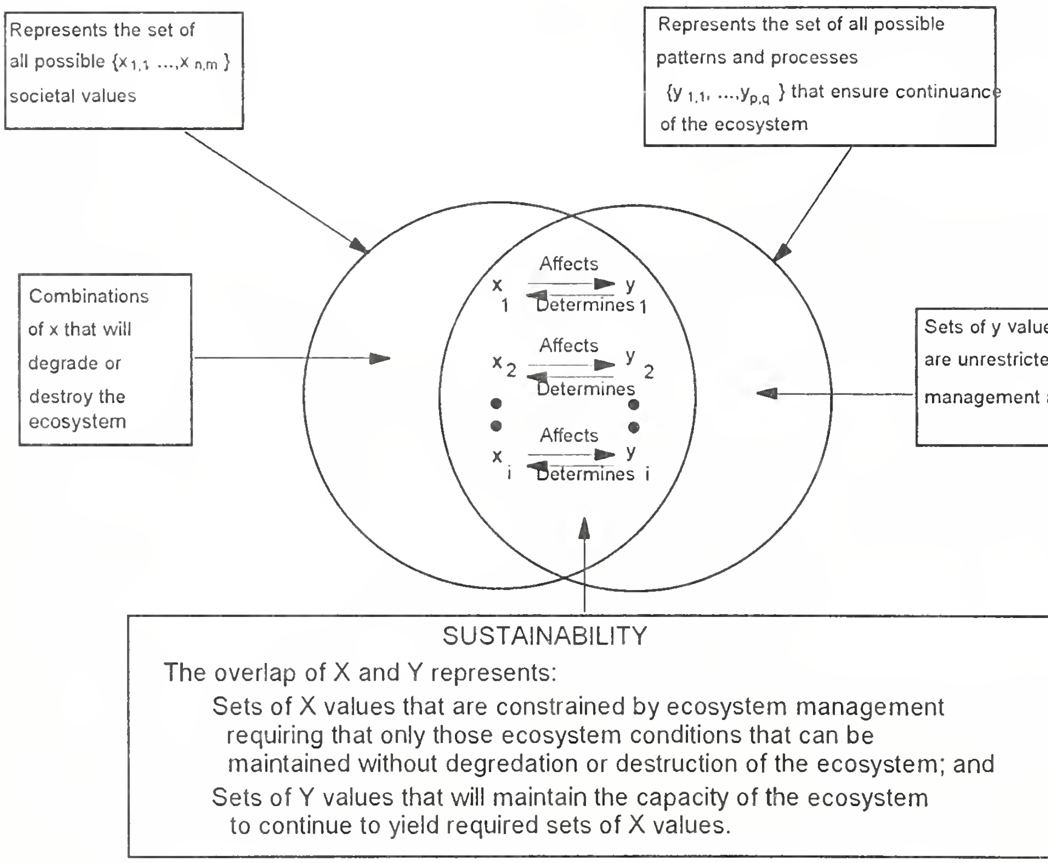


Figure III-8. The relation between selection of social values required from the ecosystem, their effects on ecosystem patterns and processes, and the constraints that those in turn place on the realization of x_j values.

The right-hand sector of the overlapping circles is represented (fig. III-8) as the set of conditions for patterns and processes that would not be influenced by any management objectives, a wilderness condition. In practice, few places in the continental United States are in this condition at the moment. The management conditions that we are considering here are those ecosystem procedures that are active largely at the stand scale, such as felling or thinning, whether for timber or wildlife habitat, specific actions to maintain water yield and quality, protection against fire, and so

on. Even a wilderness does have an active management condition, one of exclusion of other $X_{i,k}$.

The requirement to achieve sustainability--if adhered to--demands a negotiation between potential users of the ecosystem over who will restrain their demands and how this will be done. To date, such restraint has not been required, no precise systems have been developed for calculating when it was necessary, and restraint was often notably lacking, which is why we have degraded ecosystems. The management processes of iterating x_j and y_j has been described as the lacing model (page 18).

To summarize, we define sustainability in these terms:

Sustainability: an ecosystem is sustainable for a set of goods, services, and states in amounts x_j if the corresponding y_j are maintained such that the x_j can continue to be produced in the future.

Define Units of Ecosystem Sustainability

To calculate our units, we first measure these characteristics of the forest that must be sustained, y_j, and the amount or extent to which they are actually sustained in the forest, called s_j (table III-2).

Table III-2. Quantities and ratios required in calculating the Pinchot Standard and the Pinchot Efficiency. An example is given in table III-3.

	For each good, service, or state			
The management target set (column III, table III-3)	x_1	x_2	...	x_p
What is actually obtained	r_1	r_2	...	r_p
Ratio	$\frac{r_1}{x_1}$	$\frac{r_2}{x_2}$	...	$\frac{r_p}{x_p}$
What ecological properties must be sustained (column V, table III-3)	y_1	y_2	...	y_p
What is actually sustained	s_1	s_2	...	s_p
Ratio	$\frac{s_1}{y_1}$	$\frac{s_2}{y_2}$	...	$\frac{s_p}{y_p}$

A ratio, $\frac{s_j}{y_j}$, is the proportional extent to which ecological processes required to maintain the yield of

s_j are being sustained. The Pinchot Standard is the product of the ratios, $\frac{s_j}{y_j}$, where each of the individual ratios is not permitted to exceed 1.

$$\text{Pinchot Standard} = \prod^{j=1,\ldots,P} A_j \quad \text{where} \quad A_j = \frac{s_j}{y_j} \ \text{for} \ \frac{s_j}{y_j} \le 1$$

$$\text{and} \quad A_j = 1 \ \text{for} \ \frac{s_j}{y_j} > 1,$$

where P is the number of goods, services, and states that were sought from the ecosystem.

We then measure what is set as a goal for each of the required values or goods; that is, the x_j, and the amount actually obtained, which we term, r_j. The ratio, $\frac{r_j}{x_j}$, is the proportional realization of each good, service or state.

$$\text{Pinchot Efficiency} = \prod^{j=1,\ldots P} \frac{r_j / x_j}{y_j / s_j} \cdot \textit{forest area}^{-1}$$

To be sustained, a forest must be managed to a Pinchot Standard of 1. The owners and users of the ecosystem must agree on the selection and amount of the X_j values. This Pinchot Standard can be applied to all ecosystems. It acts as a universal standard that tells us if the quantity and type of values and goods being taken are too much to be sustained. Because it is a product of ratios, the Pinchot Standard does not depend on the type of ecosystem, whether it is of high or low productivity or if it is an old-growth or plantation forest, nor is it necessarily determined by whether much or little is being asked of the ecosystem. It is simply an index of what is asked relative to its effect on patterns and processes.

In contrast, the Pinchot Efficiency does vary between ecosystems. For any individual term in the calculation, if actual yield is greater than set, then the numerator is greater than 1. Note the reversal of the *s* and *y* terms in the denominator compared with the calculation of the Pinchot Standard. This reversal means that if the patterns and processes continue at a greater rate than that specified, then the denominator becomes less than 1 and so acts to increase the whole term used in calculating the Pinchot Efficiency. As the number of terms increases--more values or goods were sought from the forest--then the Pinchot Efficiency would increase if each of the component values were greater than 1. The best way to increase the Pinchot Efficiency for a forest is to satisfy the yield of many values or goods, each one efficiently. The standardization by area of forest is important to allow a uniform comparison.

Describe Objective Measures: the Pinchot Standard and the Pinchot Efficiency

The important use that can be made of the Pinchot Standard and the Pinchot Efficiency is that they give a progressive assessment of the condition and performance of the forest relative to the demands made on it. We can specify four requirements for these calculations.

- An estimate of the errors associated with the measurements is needed. Initially, at least, simple measures of both y_j and s_j may suffice. Complication of measurement is not a virtue in itself, but what is needed is an estimate of the probability of continued yield of the goods, services, and states that are desired. New information may make the estimates of the y_j and s_j more complex, but also more precise and accurate.

- The first estimates of y_j and s_j will be influenced by a mixture of both scientific and local knowledge and various probabilities of certainty to both may be attached.

- Some of the x_j and some of the y_j values may be causally connected, and increasingly sophisticated y's may be developed as the links between them become apparent. Independence cannot be assumed in either x_j or y_j; indeed, the whole objective of ecosystem management assumes interactions. A consequence is a lack of validity to the assumption of independence that would usually be required in calculating joint probabilities.

To implement the system described here, the important task is to construct a **scale-specific** model of the ecological system that is integrated to the y_j and x_j network. The accuracy of that model would depend on the required accuracy for the Pinchot Standard and the Pinchot Efficiency, which in turn depends on how these measures will be used in the management system.

An appropriate calculation framework may be to use a Bayesian belief network framework, which is particularly valuable where information of different certainties is being combined and the information about particular elements must be updated. Such networks can handle a variety of human inference patterns including complex reasoning and smooth integration of likelihoods when one event has multiple causes. The Bayesian approach would be particularly useful for calculating the Pinchot Standard and the Pinchot Efficiency from condensed information in the y_j and s_j values.

An Example Calculation of the Pinchot Standard and Pinchot Efficiency

An example of the evaluation process is illustrated by table III-3. First, we assume that a process of evaluation of $X_{i,k}$ values (column I) has resulted in a decision that a particular forest will be managed for two societal values: timber production and conservation of a species of turtle. Assume the turtle has been identified as an endangered species nationally, but it occurs locally. Part of the task of the first stage of evaluation is to identify what is required of each value (column II) and specifying the x_j required (column III). The condition of the forest, y_j that will yield these values of x_j has then to be defined (column IV), and the patterns and processes required to maintain this condition must be specified (column V). Then, a joint evaluation is made (column VI). The joint evaluation might be made in terms of area of forest required for the two purposes, which would

clearly be subject to debate and experiment that may influence the way that future condition would be calculated.

What this process illustrates is that the need for competing communities of interest to be very specific in their requirements and the ecological implication of those requirements. A timber requirement cannot be specified simply in terms of "as much timber as possible," nor a conservation requirement as "reserve all the forest for this purpose."

Table III-3. Requirement for the sample calculation of the Pinchot Standard and Efficiency.

The Evaluation Process					
I	II	III	IV	V	VI
$X_{i,k}$ Value	Evaluation procedure for X	x_j Specific management objectives for the ecosystem	$Y_{i,k}$ Required future condition of the ecosystem	y_j Patterns and processes	Joint evaluation function
Turtles	What is it that we want from this population? If we require conservation, then do we have a definition of genetic diversity for this animal?	Definition of "breeding population," that will provide the required genetic diversity	The area of ecosystem and ecological conditions required to maintain the breeding population	The ecological conditions that maintain the habitat area and quality that turtles require	The different evaluation functions for different x_j in relation to their y_j. In the first case, this might be made on the basis of area required for each use and then possible sharing of areas. If objectives still cannot be met, then the $x_{i,k}$ selected and x_j calculated must be reevaluated
Timber yield	Evaluation of "purpose" for the yield	Specified annual yield in board feet of particular quality for a particular purpose	Specification of the ecosystem with particular growth rates, which could be a set of options	Ecosystem growth rates sufficient, over known areas, to deliver the required yield	

The y_j to maintain a breeding population of turtles will have a very different calculation from that required to maintain a specific growth rate of timber. In these two cases, at least some spatial exclusion could be needed, though it may not be complete. If turtles were known to favor a particular area for breeding within a known forest, then that area would be a component of the y_j for turtles. For this type of variable, y_j becomes a composite, but some important parts are specified as local areas or conditions, not as theoretical rates or ideals about population processes. Clearly, the monitoring of the turtle population would be the primary s_j, although maintaining the breeding area may be included. Providing a population monitoring system specific to this problem can be devised; then, any need to respond to changes in the turtle population should be detected quickly. This approach requires a focus on evaluating specific functional aspects of the ecosystem, its patterns and processes, that determine the goods, services, and states that were required.

Monitoring timber production is more complex, particularly in relation to estimating growth rates. The difficulty with traditional growth and yield models based on mensurational principles has been their failure to incoporate sufficient ecological processes that control growth (Leary 1984). Problems with ecologically based site index models often lie with the attempt to apply global models locally. The important requirement is to measure actual growth rather than depending on growth and yield models.

For both of these variables, the estimated indicator of the forest's continuing capacity, y_j, and its corresponding actual measurement s_j, can be envisaged, at the first assessment at least, as represented by simple variables. The calculation of both y_j and s_j need not be more complex if more rapid or detailed assessment of forest condition is needed. The important point is that forest health can be approximated with our measures of ecosystem sustainability.

MECHANISMS OF SOCIETAL PARTICIPATION AND ACTION

This framework for ecosystem management provides a structure to deal with thorny conflicts, particularly over management objectives. Different scales of government exert authority over managing ecosystems on Federal public land. Questions arise, for example, about the precedence of local residents for access to products from ecosystems in their immediate vicinity or the supremacy of national objectives established for Federal lands because the lands are owned collectively and equally by the American people.

The proposed units--Pinchot Standard and Pinchot Efficiency--provide a path for resolving conflicts in societal demands by indentifying:

- What people want from the ecosystem;
- The ecological requirements necessary to produce what people want; and
- Priorities for ecosystem goods, services, and states.

Geographic scaling presents especially difficult problems for setting priorities. We have brainstormed workable solutions to bringing together good science, local and wide interests, and practical management to achieve sustainable ecosystems through effective and coordinated planning. We proposed that an impartial, recognized authority is needed to implement the procedure to calculate ecosystem management for sustainability, and to see that the process of conflict resolution proceeds effectively. We decided that defining the resolution process might be thought of as an "ecosystem charter" and that the authority overseeing the resolution process might be called the "ecosystem authority." And we developed these ideas based on democratic processes far enough to propose strategies related to the range of democratic mechanisms characterized by Hamiltonian to Jacksonian philosophies.

But ultimately, we decided we were not the appropriate group to develop the strategy for seeking societal consensus and incorporating high-quality science to achieve sustainable-ecosystem management. The framework presented here could be used by a small team representing knowledge from the social sciences (including political science, economics, sociology, management science, and psychology) to propose the societal process for lacing society's values to the ecological capacity of public lands to achieve ecosystem sustainability.

A ROLE FOR RESEARCH IN SUSTAINABLE-ECOSYSTEM MANAGEMENT

The role for research in ecosystem management is both greatly expanded and more clearly specified than is the current role. It will require scientists from a broader array of disciplines, more integration of disciplines, more funding, and redirection of current research, as proposed in the National Research Council report (NRC 1990). Managing as an experiment is not only critical to improving ecosystem sustainability, it is required to accumulate empirical evidence on ecosystem response and to develop the theory of ecosystems that is now lacking.

A broad range of science is needed to support the decision process developed in the lacing model (fig. III-9). Areas of supporting research are discussed briefly. Needed research is couched in these terms. The integration of what people want and what is possible in biological and physical terms should be the basis for sustainable-ecosystem management. Science has a long way to go to achieve this objective, and hence further conceptual development, like the building of our framework, is needed.

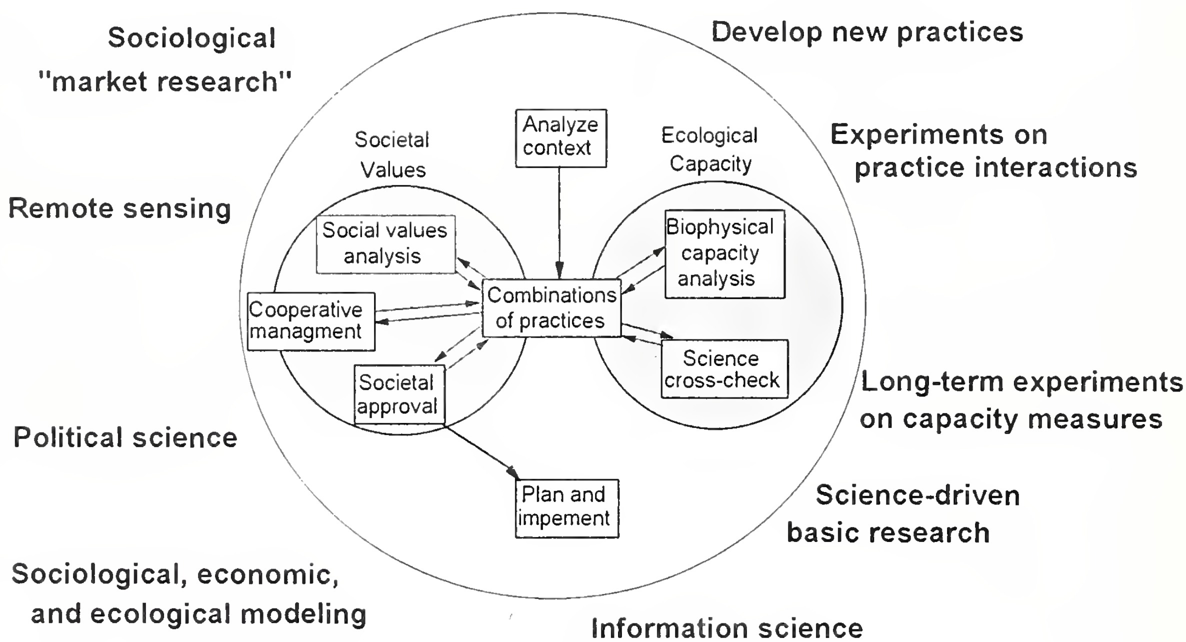


Figure III-9. The relation of research disciplines to planning, decisionmaking, and implementing sustainable-ecosystem management.

Integrating societal values and the capacity of the ecosystem to provide them. This framework ties together social values and the social and natural sciences into a common framework for sustainable-ecosystem management. Ultimately, the success of this integration will be determined by developing measures to evaluate whether objectives have been achieved. These measures should be based on understanding:

- The broad range of societal values ("products") desired from public lands,
- Ecosystem patterns and processes required to produce each product, and
- The interactions between ecosystem patterns and processes.

No existing unit simultaneously describes societal acceptance and ecosystem patterns and processes, yet evaluating the success of management requires such a unit. We have begun to develop this idea by proposing the Pinchot Standard and Pinchot Efficiency to express ecosystem patterns and processes thought to be required for their sustained production. Further developing of these concepts should be a high research priority.

Develop new practices. A major effort is needed to build a creative environment for designing new practices and combinations of practices. Research has a role in applying the latest knowledge and being innovative. An example where innovation is needed in eastern Oregon and Washington is reducing the potential for catastrophic wildfire. The most common practice traditionally is to reduce fuel loads by underburning, but underburning has several important drawbacks. Underburning generates potentially harmful smoke, fire can escape and become catastrophic, and fire depletes nutrients from soils that are often nutrient deficient. Innovations might include mechanically incorporating fuels into mineral soils and research on planting fire-resistant vegetation as fire breaks.

Experiments on practice combinations. If management becomes an experiment, science and management will become difficult to distinguish. Researchers, along with other members of society, would fully participate in making decisions on how to manage the ecosystem; that is, in defining the experiment that is management. Management practices would be laid out in an experimental fashion that would focus on trying a variety of approaches, some of which may be thought to be likely to fail or include practices that people are not likely to want. Science requires this variety to test hypotheses and to learn from experience. This shift away from "best" practices--in which new practices were avoided even if there was only a remote chance that they may not produce the desired result--is important.

Research on individual practices at the ecosystem scale is not feasible because the combination of too many possible practices and too many different localities would not develop an empirical basis for their effects. Research at the ecosystem scale must begin to focus on multiple practices and practice interactions. Because these sustainability experiments will be applied to larger ecosystems, they will necessarily combine many interacting ecological processes and management effects. Reductionist scientists will correctly argue that such studies will be difficult to interpret. In some locations, therefore more intensive, more traditional experiments will need to be jointly applied, in a nested fashion, to tease apart these important interactions.

Long-term experiments to evaluate measures and indicators of ecological capacity. Measures and indicators of ecological capacity to produce future ecosystem products must be studied in long-term experiments to determine their relation to future products and among themselves. Experiments would include a wide range of treatments hypothesized to increase, maintain, or decrease future products. For example, if soil organic matter is chosen as an indicator of energy capture by green plants, experiments could measure effects on plant growth of increasing or decreasing organic matter. Understanding how to interpret conflicting trends in different health

measures will also be essential; for example, increasing soil organic matter may increase plant growth but decrease the flow of water through increased transpiration.

Remote sensing. Refining methods to monitor capacity at various geographic scales is also a critical need. Further development of remote sensing techniques is important at broad geographic scales and for monitoring activities on adjacent private lands, as a basis for cooperative management. Images made with Federal satellites should be fully available to scientists and managers.

Retrospective development of ecosystem theory. While waiting for the results of long-term experiments and managing as an experiment, scientists need to extract available knowledge from experience. High priority should be given this effort because it will provide important, mostly qualitative information that can guide the development of sustainable-ecosystem management. This work should focus on understanding past, interrelated changes in ecosystem capacity and societal needs and wants, not so much for making projections or identifying target conditions, but rather to better understand the societal and ecological processes that control sustainability. It is the development of this theory that will allow us to chart desirable future directions.

A role for "basic" science. The natural resource research community had difficulty promoting research that does not appear critical to answering the ever-present crisis. This problem has eroded the science base for applied science (NRC 1990). What is needed may simply be better understanding of the connection between much of this work and the critical issues of today and, especially, tomorrow. Ecosystem management will need to be based on a new theory of ecosystems that must in turn be based on sound, fundamental science. A continual revisiting of our fundamental premises will be required to prevent a static science paradigm.

Cross-check model. Regardless of how central research becomes to management, science will always have an important role as independent evaluator of management; a role that identifies current and future problems as information is developed and synthesized. A priority for research then is to develop the cross-check model (table III-3), which could be used to independently evaluate management and research closely linked to management. Developing this model and its continual updating can also help prevent a stagnant science paradigm from developing as a foundation for ecosystem management.

Social sciences. Especially important will be an expanded role for social scientists, including those who specialize in economics, market research, political science, conflict resolution, and institutional design. Methods of determining societal desires have generally not yet been applied to natural resource issues. Developing efficient decision processes that make society a full partner is also a critical need. Further elaboration on the social science contribution to support ecosystem management is a critical need and must be further elaborated.

Information science. With a greater emphasis on information and its transfer between different geographic scales of management, information sciences should be brought to bear on public land management. Application of emerging telecommunications and computing technologies is essential to better inform the decision process. Broader participation by diverse societal communities requires the skills of information specialists who can communicate complex scientific and management concepts clearly and accurately.

EPILOGUE

Our approach to sustainable-ecosystem management depends on:

- Adopting the lacing model that establishes an environment for interactions among managers, scientists, and society to define the objective of increasing ecosystem sustainability, the overlap between what people want and what is ecologically possible in the long term;

- Developing further the objective measures of ecosystem sustainability. We propose the Pinchot Standard and the Pinchot Efficiency as initial models. These measures require selecting the ecological patterns and processes needed for each product that people want;

- Applying management as an experiment in which outcomes are forecast and actual outcomes are compared with them, an array of treatments replaces "best practice" and society and scientists jointly design the experiment with managers.

The proposed framework requires changes in public land management agencies to adopt the ideas of lacing and management as an experiment. It also depends on a commitment to continue to develop the conceptual basis of ecosystem management.

We hope these pages convey our sense of urgency, the need for fundamental change in how public lands are managed, the social and biological consequences of not changing, and the need for broad public understanding that their expectations cannot exceed the capacity of the ecosystem to meet them.

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ANONYMOUS PEER REVIEW

Attached are the sections of the ms "A broad, strategic framework for sustained-ecosystem management" which were sent to me for comment by Prof. Bruce Dancik on your behalf.

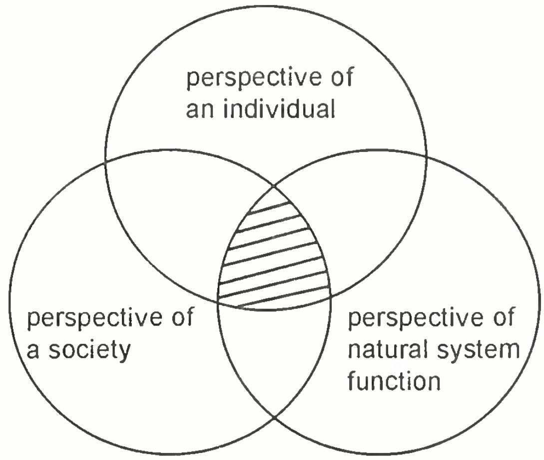
I have made extensive comments on the ms and will not attempt to summarize them here. My differences of opinion/interpretation are, I believe, all arguable and are offered to assist the writers [to] communicate rather than in opposition to their views. Although I did not appear to have the full paper, there were few problems. The section in pp. 59-70 appears to be supported by other parts of the document and it would have been helpful to have had that material. I suspect many of my questions on that part of the ms are answered elsewhere.

This has been exciting reading and the amount of ink on the ms should not be construed as a evidence of "problems." In general, this is written in a clear and concise manner that is highly readable. This is especially true when one considers the complexity of the issues involved. More importantly, the concepts put forward and developed are exceptional in several ways. They move away from the traditional notions of "right things to do" and move strongly towards what ecosystem values (states) do we wish to maintain and what strategies might be expected to achieve such maintenance. The move away from prescriptive forestry, and towards analysis for reasoned intervention. They move away from vague social imperatives, and towards systematic recognition of ecosystem values as held by a society. In short, this is not a traditional document.

The absence of dominant tradition in the paper is good from my perspective, but will pose serious difficulty for the traditionally-minded reader. This is bound to raise the issue of who is being addressed. I would argue this is addressed to everybody, in the sense of anybody who is willing to read without superimposing a traditional perspective. This paper does not require that a reader accept (or buy into) the proposed new paradigm (if that is the right word), it merely expects the reader to suspend traditional views *while reading*. This paper offers a reasoned approach to ecosystem management, which differs from others I have seen by virtue of the level and nature of the reasoning offered. A reader must surely conclude that this is not just a better way to do what we do. Rather, it is finally a way to discover what it is we might consider doing towards building a better future.

Section I: Recommendations. These are a tad cryptic when taken out of context before reading the piece. If they appeared at the end they would be better appreciated for what they say. There is substantial risk they will not be interpreted as the writers intend, if they appear as stated at the beginning of the piece. I read them first and said to myself "ho hum, here we go again" - but what follows is *not* ho hum!

Section II: Framework. This is the crucial section in terms of carrying a reader, and I think it is well done. The matter of establishing a societal view of what management is, and what/who it is for, is of particular importance. I have come to see this problem in terms of three intersecting perspectives; that of an individual person, that of a society as a whole, and that of natural system dynamics as these actually operate in nature.



In general, these perspectives are articulated as independent views by individuals standing in the non-overlapping regions of the three circles. That is, we tend to see an ecosystem from one or the other of the three perspectives, and to yell at the folks holding the other two perspectives. The solution clearly (to me, at least) lies in each of us finding our way into the 'overlap,' so we can discuss the problems looking outward as it were.

The notion of information as a primary resource does not come easily to me. I tend to think of primary resources as ones that have the inherent ability to reproduce, or at the other extreme are fixed in nature. Clearly, information does not fit such a view. As I read along, the whole thing became more comfortable, but I was not convinced. The idea does not appear to be essential for a reader to follow the logic of the paper, and it may cause readers to stop and ponder, thus losing the real train of thought. This is a risk because the summary makes quite a deal of information being a resource, while in the paper itself that concept is not essential to understanding the main thrust ofr ecosystem management.

Ideas like managing across boundaries and management as an experiment are, in my view essential to a reasoned approach to ecosystem management. The book by Carl Walters (University of British Columbia) on "adaptive management" makes much of this idea and I have found it powerful in application. The authors may want to look at the Walters book. It is more of a scientists view of how to "do it", while the present paper has society much more explicitly in the picture. I believe it will always be easier to get the 'science' in, than to get 'society' in, therefore I see the present paper as a significant improvement on his adaptive management.

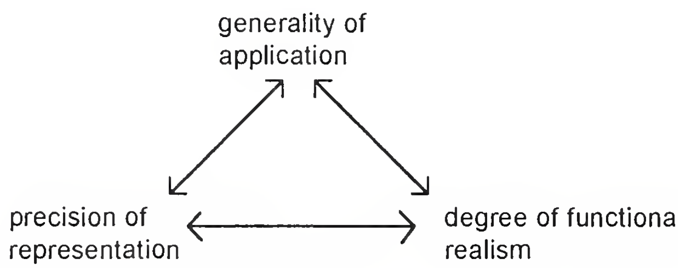
The section on 'the lacing model' is a bit cryptic. The idea is attractive and the reader does not get enough to really grasp the structure. Since I do not have the whole paper I was not able to see it in its fully developed form.

Section III: Background and theory. This section is sufficiently comprehensive I hesitate to make *any* general comment. The fundamental premises are a neat way to get started. Some words on the degree to how they constitute the necessary and sufficient basis for what follows would be helpful.

One place where I really stumbled with the text was the notion of nature as stochastic (p 30). I have come to believe that the real definition of stochastic when used by and ecologist is "I don't understand the cause-effect here." Ecosystems are hard to predict, yes, but as the authors note elsewhere they can be forecast. The piece on stochasticity did not leave me assured that critical reasoning was being applied in this area.

The section on premises for the role of society was really good reading. One thing that kept coming to mind was a paper in Ecological Monographs last year by Holling (University of Florida) which dealt at length with the matter of temporal and spatial scales in natural system dynamics. Of particular interest to the present work was his notion that natural processes tend to be "lumpy" when plotted on temporal and spatial scales that embrace differences by order of magnitude. It would be interesting to map the social features of pp 33-43 in the manner of his article.

Something that might help here is the idea presented by Levins (I believe in the paper you reference) that all models have three properties, realism of function, generality of application, and precision of representation. He argued, and I happen to agree, that these three properties tend to be mutually exclusive. My recollection of his idea is in the following diagram. Thus all gains in realism of function in a model are made at the expense of the amount of nature that they represent. Equally, gains in precision of representation (statistical 'goodness') are made at the expense of the ability of the model to represent future function, and so on.



The section on ecosystem management fundamentals on pp 53-60 will strike traditionalists from either basic science, or, from management as a tad off-the-wall. I think it is *super* (what does that say) but I suspect many readers will cavil at the approach.

The introduction of the matrix approach (pp 60-70) is a powerful way to put it all together, but runs a risk of losing anyone lacking basic matrix language. The last thing you need is people saying that "scientists have once again made it so complex that only they can understand." The corollary to that is the implication that scientist are trying to gain/retain control. At the same time, the matrix approach is an extremely effective way of capturing an incredible amount of complexity in a simple format, but I guess that is what makes it dangerous. There may be a minor notational problem in p 61.

I believe it would be dangerous to end the paper with the matrix material. That would probably have the impact of limiting the readership to a dangerously small subset of "people."

Let me urge you to pursue this excellent work. Don't let the ideas on these pages become academic! Make them workable, and get them working, in the real world! You are well past the point of an academic exercise so just *go do it!*

This has been the most interesting piece on resource management for society that I have seen in a long time. The paper represents a qualitatively different thought process than the reigning paradigm, and it deserves wide distribution. **May I place my request now [for] a copy of the final paper as soon as that is possible.**